

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization  
International Bureau



(43) International Publication Date  
21 June 2001 (21.06.2001)

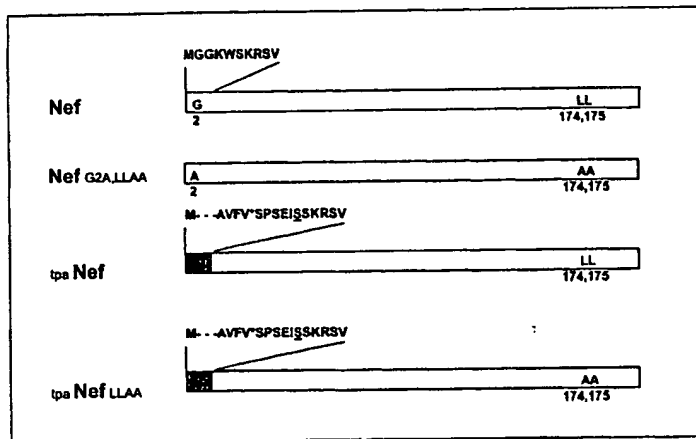
PCT

(10) International Publication Number  
WO 01/43693 A2

- (51) International Patent Classification<sup>7</sup>: A61K [US/US]; 126 East Lincoln Avenue, Rahway, NJ 07065-0907 (US).
- (21) International Application Number: PCT/US00/34162
- (22) International Filing Date:  
15 December 2000 (15.12.2000)
- (25) Filing Language: English
- (26) Publication Language: English
- (30) Priority Data:  
60/172,442 17 December 1999 (17.12.1999) US
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- (81) Designated States (national): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CR, CU, CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.
- (84) Designated States (regional): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).
- Published:  
— Without international search report and to be republished upon receipt of that report.

[Continued on next page]

(54) Title: POLYNUCLEOTIDE VACCINES EXPRESSING CODON OPTIMIZED HIV-1 NEF AND MODIFIED HIV-1 NEF



(57) Abstract: Pharmaceutical compositions which comprise HIV Nef DNA vaccines are disclosed, along with the production and use of these DNA vaccines. The nef-based DNA vaccines of the invention are administered directly introduced into living vertebrate tissue, preferably humans, and express the HIV Nef protein or biologically relevant portions thereof, inducing a cellular immune response which specifically recognizes human immunodeficiency virus-1 (HIV-1). The DNA molecules which comprise the open reading frame of these DNA vaccines are synthetic DNA molecules encoding codon optimized HIV-1 Nef and derivatives of optimized HIV-1 Nef, including nef modifications comprising amino terminal leader peptides, removal of the amino terminal myristylation site, and/or modification of the Nef dileucine motif. These modifications may effect wild type characteristics of Nef, such as myristylation and down regulation of host CD4.

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*For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.*

## TITLE OF THE INVENTION

5 POLYNUCLEOTIDE VACCINES EXPRESSING CODON OPTIMIZED HIV-1  
NEF AND MODIFIED HIV-1 NEF

## CROSS-REFERENCE TO RELATED APPLICATIONS

10 This application claims the benefit, under 35 U.S.C. §119(e), of U.S.  
provisional application 60/172,442, filed December 17, 1999.

## STATEMENT REGARDING FEDERALLY-SPONSORED R&amp;D

Not Applicable

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## REFERENCE TO MICROFICHE APPENDIX

Not Applicable

## FIELD OF THE INVENTION

20 The present invention relates to HIV Nef polynucleotide pharmaceutical  
products, as well as the production and use thereof which, when directly introduced  
into living vertebrate tissue, preferably a mammalian host such as a human or a  
non-human mammal of commercial or domestic veterinary importance, express the  
HIV Nef protein or biologically relevant portions thereof within the animal, inducing  
25 a cellular immune response which specifically recognizes human immunodeficiency  
virus-1 (HIV-1). The polynucleotides of the present invention are synthetic DNA  
molecules encoding codon optimized HIV-1 Nef and derivatives of optimized HIV-1  
Nef, including nef mutants which effect wild type characteristics of Nef, such as  
myristylation and down regulation of host CD4. The polynucleotide vaccines of the  
30 present invention should offer a prophylactic advantage to previously uninfected  
individuals and/or provide a therapeutic effect by reducing viral load levels within an  
infected individual, thus prolonging the asymptomatic phase of HIV-1 infection.

## BACKGROUND OF THE INVENTION

Human Immunodeficiency Virus-1 (HIV-1) is the etiological agent of acquired human immune deficiency syndrome (AIDS) and related disorders. HIV-1 is an RNA virus of the Retroviridae family and exhibits the 5' LTR-*gag-pol-env*-

5 LTR 3' organization of all retroviruses. The integrated form of HIV-1, known as the provirus, is approximately 9.8 Kb in length. Each end of the viral genome contains flanking sequences known as long terminal repeats (LTRs). The HIV genes encode at least nine proteins and are divided into three classes; the major structural proteins (Gag, Pol, and Env), the regulatory proteins (Tat and Rev); and the accessory proteins (Vpu, Vpr, Vif and Nef).

10 The *gag* gene encodes a 55-kilodalton (kDa) precursor protein (p55) which is expressed from the unspliced viral mRNA and is proteolytically processed by the HIV protease, a product of the *pol* gene. The mature p55 protein products are p17 (matrix), p24 (capsid), p9 (nucleocapsid) and p6.

15 The *pol* gene encodes proteins necessary for virus replication; a reverse transcriptase, a protease, integrase and RNase H. These viral proteins are expressed as a Gag-Pol fusion protein, a 160 kDa precursor protein which is generated via a ribosomal frame shifting. The viral encoded protease proteolytically cleaves the Pol polypeptide away from the Gag-Pol fusion and further cleaves the Pol polypeptide to the mature proteins which provide protease (Pro, P10), reverse transcriptase (RT, P50), integrase (IN, p31) and RNase H (RNase, p15) activities.

The *nef* gene encodes an early accessory HIV protein (Nef) which has been shown to possess several activities such as down regulating CD4 expression, disturbing T-cell activation and stimulating HIV infectivity.

25 The *env* gene encodes the viral envelope glycoprotein that is translated as a 160-kilodalton (kDa) precursor (gp160) and then cleaved by a cellular protease to yield the external 120-kDa envelope glycoprotein (gp120) and the transmembrane 41-kDa envelope glycoprotein (gp41). Gp120 and gp41 remain associated and are displayed on the viral particles and the surface of HIV-infected cells.

30 The *tat* gene encodes a long form and a short form of the Tat protein, a RNA binding protein which is a transcriptional transactivator essential for HIV-1 replication.

The *rev* gene encodes the 13 kDa Rev protein, a RNA binding protein. The Rev protein binds to a region of the viral RNA termed the Rev response element

(RRE). The Rev protein is promotes transfer of unspliced viral RNA from the nucleus to the cytoplasm. The Rev protein is required for HIV late gene expression and in turn, HIV replication.

Gp120 binds to the CD4/chemokine receptor present on the surface of helper  
5 T-lymphocytes, macrophages and other target cells in addition to other co-receptor molecules. X4 (macrophage tropic) virus show tropism for CD4/CXCR4 complexes while a R5 (T-cell line tropic) virus interacts with a CD4/CCR5 receptor complex. After gp120 binds to CD4, gp41 mediates the fusion event responsible for virus entry. The virus fuses with and enters the target cell, followed by reverse transcription of its  
10 single stranded RNA genome into the double-stranded DNA via a RNA dependent DNA polymerase. The viral DNA, known as provirus, enters the cell nucleus, where the viral DNA directs the production of new viral RNA within the nucleus, expression of early and late HIV viral proteins, and subsequently the production and cellular release of new virus particles. Recent advances in the ability to detect viral load  
15 within the host shows that the primary infection results in an extremely high generation and tissue distribution of the virus, followed by a steady state level of virus (albeit through a continual viral production and turnover during this phase), leading ultimately to another burst of virus load which leads to the onset of clinical AIDS. Productively infected cells have a half life of several days, whereas chronically or  
20 latently infected cells have a 3-week half life, followed by non-productively infected cells which have a long half life (over 100 days) but do not significantly contribute to day to day viral loads seen throughout the course of disease.

Destruction of CD4 helper T lymphocytes, which are critical to immune defense, is a major cause of the progressive immune dysfunction that is the hallmark  
25 of HIV infection. The loss of CD4 T-cells seriously impairs the body's ability to fight most invaders, but it has a particularly severe impact on the defenses against viruses, fungi, parasites and certain bacteria, including mycobacteria.

Effective treatment regimens for HIV-1 infected individuals have become available recently. However, these drugs will not have a significant impact on the  
30 disease in many parts of the world and they will have a minimal impact in halting the spread of infection within the human population. As is true of many other infectious diseases, a significant epidemiologic impact on the spread of HIV-1 infection will only occur subsequent to the development and introduction of an effective vaccine. There are a number of factors that have contributed to the lack of successful vaccine

development to date. As noted above, it is now apparent that in a chronically infected person there exists constant virus production in spite of the presence of anti-HIV-1 humoral and cellular immune responses and destruction of virally infected cells. As in the case of other infectious diseases, the outcome of disease is the result of a balance between the kinetics and the magnitude of the immune response and the pathogen replicative rate and accessibility to the immune response. Pre-existing immunity may be more successful with an acute infection than an evolving immune response can be with an established infection. A second factor is the considerable genetic variability of the virus. Although anti-HIV-1 antibodies exist that can neutralize HIV-1 infectivity in cell culture, these antibodies are generally virus isolate-specific in their activity. It has proven impossible to define serological groupings of HIV-1 using traditional methods. Rather, the virus seems to define a serological "continuum" so that individual neutralizing antibody responses, at best, are effective against only a handful of viral variants. Given this latter observation, it would be useful to identify immunogens and related delivery technologies that are likely to elicit anti-HIV-1 cellular immune responses. It is known that in order to generate CTL responses antigen must be synthesized within or introduced into cells, subsequently processed into small peptides by the proteasome complex, and translocated into the endoplasmic reticulum/Golgi complex secretory pathway for eventual association with major histocompatibility complex (MHC) class I proteins. CD8<sup>+</sup> T lymphocytes recognize antigen in association with class I MHC via the T cell receptor (TCR) and the CD8 cell surface protein. Activation of naive CD8<sup>+</sup> T cells into activated effector or memory cells generally requires both TCR engagement of antigen as described above as well as engagement of costimulatory proteins. Optimal induction of CTL responses usually requires "help" in the form of cytokines from CD4<sup>+</sup> T lymphocytes which recognize antigen associated with MHC class II molecules via TCR and CD4 engagement.

As introduced above, the *nef* gene encodes an early accessory HIV protein (Nef) which has been shown to possess several activities such as down regulating CD4 expression, disturbing T-cell activation and stimulating HIV infectivity. Zazopoulos and Haseltine (1992, *Proc. Natl. Acad. Sci.* 89: 6634-6638) disclose mutations to the HIV-1 *nef* gene which effect the rate of virus replication. The authors show that the *nef* open reading frame mutated to encode Ala-2 in place of Gly-2 inhibits myristolation of the protein and results in delayed viral replication rates

in Jurkat cells and PBMCs.

Kaminchik et al. (1991, *J. Virology* 65(2): 583-588) disclose an amino-terminal nef open reading frame mutated to encode Met-Ala-Ala in place of Met-Gly-Gly. The authors show that this mutant is deficient in myristolation.

5        Saksela et al. (1995, *EMBO J.* 14(3): 484-491) and Lee et al. (1995, *EMBO J.* 14(20): 5006-5015) show the importance of a proline rich motif in HIV-1 Nef which mediates binding to a SH3 domain of the Hck protein. The authors conclude that this motif is important in the enhancement of viral replication but not down-regulation of CD4 expression.

10        Calarota et al. (1998, *The Lancet* 351: 1320-1325) present human clinical data concerning immunization of three HIV infected individuals with a DNA plasmid expressing wild type Nef. The authors conclude that immunization with a Nef encoding DNA plasmid induced a cellular immune response in the three individuals. However, two of the three patients were on alternative therapies during the study, and  
15 the authors conclude that the CTL response was most likely a boost to a pre-existing CTL response. In addition, the viral load increased substantially in two of the three patients during the course of the study.

Tobery et al. (1997, *J. Exp. Med.* 185(5): 909-920) constructed two ubiquitin-nef (Ub-nef) fusion constructs, one which encoded the Nef initiating methionine and  
20 the other with an Arg residue at the amino terminus of the Nef open reading frame. The authors state that vaccinia- or plasmid-based immunization of mice with a Ub-nef construct containing an Arg residue at the amino terminus induces a Nef-specific CTL response. The authors suggest the expressed fusion protein is more efficiently presented to the MHC class I antigen presentation pathway, resulting in an improved  
25 cellular immune response.

Kim et al. (1997, *J. Immunol.* 158(2): 816-826) disclose that co-administration of a plasmid DNA construct expressing IL-12 with a plasmid construct expressing Nef results in an improved cellular immune response in mice when compared to inoculation with the Nef construct alone. The authors reported a reduction in the  
30 humoral response from the Nef / IL-12 co-administration as compared to administration of the plasmid construct expressing Nef alone.

Moynier et al. (1998, *Vaccine* 16(16): 1523-1530) show varying humoral responses in mice immunized with a DNA plasmid encoding Nef, depending upon the presence of absence of Freund's adjuvant. No data is disclosed regarding a cellular

immune response in mice vaccinated with the aforementioned DNA construct alone.

Hanna et al. (1998, *Cell* 95:163-175) suggest that wild type Nef may play a critical role in AIDS pathogenicity.

It would be of great import in the battle against AIDS to produce a  
5 prophylactic- and/or therapeutic-based HIV vaccine which generates a strong cellular immune response against an HIV infection. The present invention addresses and meets this needs by disclosing a class of DNA vaccines based on host delivery and expression of the early HIV gene, *nef*.

## 10 SUMMARY OF THE INVENTION

The present invention relates to synthetic DNA molecules (also referred to herein as "polynucleotides") and associated DNA vaccines (also referred to herein as "polynucleotide vaccines") which elicit CTL responses upon administration to the host, such as a mammalian host and including primates and especially humans, as  
15 well as non-human mammals of commercial or domestic veterinary importance. The CTL-directed vaccines of the present invention should lower transmission rate to previously uninfected individuals and/or reduce levels of the viral loads within an infected individual, so as to prolong the asymptomatic phase of HIV-1 infection. In particular, the present invention relates to DNA vaccines which encode various forms  
20 of HIV-1 Nef, wherein administration, intracellular delivery and expression of the HIV-1 *nef* gene of interest elicits a host CTL and Th response. The preferred synthetic DNA molecules of the present invention encode codon optimized versions of wild type HIV-1 Nef, codon optimized versions of HIV-1 Nef fusion proteins, and codon optimized versions of HIV-1 Nef derivatives, including but not limited to *nef*  
25 modifications involving introduction of an amino-terminal leader sequence, removal of an amino-terminal myristylation site and/or introduction of dileucine motif mutations. The Nef-based fusion and modified proteins disclosed within this specification may possess altered trafficking and/or host cell function while retaining the ability to be properly presented to the host MHC I complex and in turn elicit a  
30 host CTL and Th response.

A particular embodiment of the present invention relates to a DNA molecule encoding HIV-1 Nef from the HIV-1 jf91 isolate wherein the codons are optimized for expression in a mammalian system such as a human. The DNA molecule which encodes this protein is disclosed herein as SEQ ID NO:1, while the expressed open



reading frame is disclosed herein as SEQ ID NO:2.

In another embodiment of the present invention, a codon optimized DNA molecule encoding a protein containing the human plasminogen activator (tpa) leader peptide fused with the NH<sub>2</sub>-terminus of the HIV-1 Nef polypeptide. The DNA molecule which encodes this protein is disclosed herein as SEQ ID NO:3, while the expressed open reading frame is disclosed herein as SEQ ID NO:4.

In an additional embodiment, the present invention relates to a DNA molecule encoding optimized HIV-1 Nef wherein the open reading frame codes for modifications at the amino terminal myristylation site (Gly-2 to Ala-2) and substitution of the Leu-174-Leu-175 dileucine motif to Ala-174-Ala-175, herein described as opt nef (G2A,LLAA). The DNA molecule which encodes this protein is disclosed herein as SEQ ID NO:5, while the expressed open reading frame is disclosed herein as SEQ ID NO:6.

Another additional embodiment of the present invention relates to a DNA molecule encoding optimized HIV-1 Nef wherein the amino terminal myristylation site and dileucine motif have been deleted, as well as comprising a tPA leader peptide. This DNA molecule, opt tpanef (LLAA), comprises an open reading frame which encodes a Nef protein containing a tPA leader sequence fused to amino acid residue 6-216 of HIV-1 Nef (jfr1), wherein Leu-174 and Leu-175 are substituted with Ala-174 and Ala-175, herein referred to as opt tpanef (LLAA) is disclosed herein as SEQ ID NO:7, while the expressed open reading frame is disclosed herein as SEQ ID NO:8.

The present invention also relates to non-codon optimized versions of DNA molecules and associated DNA vaccines which encode the various wild type and modified forms of the HIV Nef protein disclosed herein. Partial or fully codon optimized DNA vaccine expression vector constructs are preferred, but it is within the scope of the present invention to utilize "non-codon optimized" versions of the constructs disclosed herein, especially modified versions of HIV Nef which are shown to promote a substantial cellular immune response subsequent to host administration.

The DNA backbone of the DNA vaccines of the present invention are preferably DNA plasmid expression vectors. DNA plasmid expression vectors utilized in the present invention include but are not limited to constructs which comprise the cytomegalovirus promoter with the intron A sequence (CMV-intA) and a bovine growth hormone transcription termination sequence. In addition, the DNA plasmid vectors of the present invention preferably comprise an antibiotic resistance

marker, including but not limited to an ampicillin resistance gene, a neomycin resistance gene or any other pharmaceutically acceptable antibiotic resistance marker. In addition, an appropriate polylinker cloning site and a prokaryotic origin of replication sequence are also preferred. Specific DNA vectors of the present invention include but are not limited to V1, V1J (SEQ ID NO:14), V1Jneo (SEQ ID NO:15), V1Jns (Figure 1A, SEQ ID NO:16), V1R (SEQ ID NO:26), and any of the aforementioned vectors wherein a nucleotide sequence encoding a leader peptide, preferably the human tPA leader, is fused directly downstream of the CMV-intA promoter, including but not limited to V1Jns-tpa, as shown in Figure 1B and SEQ ID NO:19.

The present invention especially relates to a DNA vaccine and a pharmaceutically active vaccine composition which contains this DNA vaccine, and the use as a prophylactic and/or therapeutic vaccine for host immunization, preferably human host immunization, against an HIV infection or to combat an existing HIV condition. These DNA vaccines are represented by codon optimized DNA molecules encoding HIV-1 Nef of biologically active Nef modifications or Nef-containing fusion proteins which are ligated within an appropriate DNA plasmid vector, with or without a nucleotide sequence encoding a functional leader peptide. DNA vaccines of the present invention relate in part to codon optimized DNA molecules encoding HIV-1 Nef of biologically active Nef modifications or Nef-containing fusion proteins ligated in DNA vectors V1, V1J (SEQ ID NO:14), V1Jneo (SEQ ID NO:15), V1Jns (Figure 1A, SEQ ID NO:16), V1R (SEQ ID NO:26), or any of the aforementioned vectors wherein a nucleotide sequence encoding a leader peptide, preferably the human tPA leader, is fused directly downstream of the CMV-intA promoter, including but not limited to V1Jns-tpa, as shown in Figure 1B and SEQ ID NO:19. Especially preferred DNA vaccines of the present invention include codon optimized DNA vaccine constructs V1Jns/nef, V1Jns/tpanef, V1Jns/tpanef(LLAA) and V1Jns/(G2A,LLAA), as exemplified in Example Section 2.

The present invention also relates to HIV Nef polynucleotide pharmaceutical products, as well as the production and use thereof, wherein the DNA vaccines are formulated with an adjuvant or adjuvants which may increase immunogenicity of the DNA polynucleotide vaccines of the present invention, namely by increasing a humoral response to inoculation. A preferred adjuvant is an aluminum phosphate-based adjuvant or a calcium phosphate based adjuvant,

with an aluminum phosphate adjuvant being especially preferred. Another preferred adjuvant is a non-ionic block copolymer, preferably comprising the blocks of polyoxyethylene (POE) and polyoxypropylene (POP) such as a POE-POP-POE block copolymer. These adjuvanted forms comprising the DNA vaccines disclosed herein are useful in increasing humoral responses to DNA vaccination without imparting a negative effect on an appropriate cellular immune response.

As used herein, a DNA vaccine or DNA polynucleotide vaccine or polynucleotide vaccine is a DNA molecule (i.e., "nucleic acid", "polynucleotide") which contains essential regulatory elements such that upon introduction into a living, vertebrate cell, it is able to direct the cellular machinery to produce translation products encoded by the respective nef genes of the present invention.

#### BRIEF DESCRIPTION OF THE FIGURES

Figure 1A-B show a schematic representation of DNA vaccine expression vectors V1Jns (A) and V1Jns/tpa utilized for HIV-1 nef and HIV-1 modified nef constructs.

Figure 2A-B show a nucleotide sequence comparison between wild type nef(jrfl) and codon optimized nef. The wild type nef gene from the jrfl isolate consists of 648 nucleotides capable of encoding a 216 amino acid polypeptide. WT, wild type sequence (SEQ ID NO:9); opt, codon-optimized sequence (contained within SEQ ID NO:1). The Nef amino acid sequence is shown in one-letter code (SEQ ID NO:2).

Figure 3A-C show nucleotide sequences at junctions between nef coding sequence and plasmid backbone of nef expression vectors V1Jns/nef (Figure 3A), V1Jns/nef(G2A,LLAA) (Figure 3B), V1Jns/tpanef (Figure 3C) and V1Jns/tpanef(LLAA) (Figure 3C, also). 5' and 3' flanking sequences of codon optimized nef or codon optimized nef mutant genes are indicated by bold/italic letters; nef and nef mutant coding sequences are indicated by plain letters. Also indicated (as underlined) are the restriction endonuclease sites involved in construction of respective nef expression vectors. V1Jns/tpanef and V1Jns/tpanef(LLAA) have identical sequences at the junctions.

Figure 4 shows a schematic presentation of nef and nef derivatives. Amino acid residues involved in Nef derivatives are presented. Glycine 2 and Leucine174

and 175 are the sites involved in myristylation and dileucine motif, respectively. For both versions of the tpanef fusion genes, the putative leader peptide cleavage sites are indicated with "\*", and an exogenous serine residue introduced during the construction of the mutants is underlined.

5           Figure 5 shows Western blot analysis of nef and modified nef proteins expressed in transfected 293 cells. 293 cells grown in 100 mm culture dish were transfected with respective codon optimized nef constructs. Sixty hours post transfection, supernatant and cells were collected separately and separated on 10% SDS-PAGE under reducing conditions. The proteins were transferred into a PVDF  
10       membrane and probed with a mixture of Gag mAb and Nef mAbs, both at 1:2000 dilution. The protein signals were detected with ECL. (A) cells transfected with V1Jns/gag only; (B) cells transfected with V1Jns/gag and V1Jns/nef; (C) cells transfected with V1Jns/gag and V1Jns/nef(G2A, LLAA); (D) cells transfected with V1Jns/gag and V1Jns/tpanef; (E) cells transfected with V1Jns/gag and  
15       V1Jns/tpanef(LLAA). The low case letter c and m represent medium and cellular fractions, respectively. M.W. = molecular weight marker.

              Figure 6 shows an Elispot assay of cell-mediated responses to Nef peptides. Three strains of mice, Balb/c, C57BL/6 and C3H, were immunized with 50 mcg of V1Jns/nef (codon optimized) and boosted twice with a two-week interval. Two  
20       weeks following the final immunization, splenocytes were isolated and tested in an Elispot assay against respective Nef peptide pools. As a control, splenocytes were from non-immunized naive mice were tested in parallel. Nef peptide pool A consists of all 21 Nef peptides; Nef peptide pool B consists of 11 non-overlapping peptide started from residue 1; Nef peptide pool C consists of 10 non-overlapping peptides  
25       started from residue 11. SFC, INF-gamma secreting spot-forming cells.

              Figure 7A-C show Nef-specific CD8 and CD4 epitope mapping. The immunization regime is as per Figure 6. Mouse splenocytes were isolated and fractionated into CD8<sup>+</sup> and CD8<sup>-</sup> cells using Miltenyi's magnetic cell separator. The resultant CD8<sup>+</sup> and CD8<sup>-</sup> cells were then tested in an Elispot assay against individual  
30       Nef peptides. SFC, INF-gamma secreting spot-forming cells. The mice strains tested are Balb/c mice (Figure 7A), C57BL/6 mice (Figure 7B), and C3H mice (Figure 7C).

              Figure 8A-C show identification of a Nef CTL epitope. Splenocytes from nef immunized C57BL/6 mice were stimulated *in vitro* with peptide-pulsed, irradiated naive splenocytes for 7 days. Following the *in vitro* stimulation, cells were harvested

and tested in a standard  $^{51}\text{Cr}$ -releasing assay using peptide pulsed EL-4 cells as targets. Open symbol, specific killings of EL-4 cells without peptide; solid symbol, specific killing of EL-4 cells with peptide. Panel A - peptide Nef 51-70; Panel B - peptide Nef 60-68, Panel C - peptide Nef 58-70.

5        Figure 9A-B shows a comparison of the immunogenicity of codon optimized DNA vaccine vectors expressing Nef and modified forms of Nef C57BL/6 mice, five per group, were immunized with 100 mcg of the indicated nef constructs. Fourteen days following immunization, splenocytes were collected and tested against the Nef CD8 (aa58-66) and CD4 (aa81-100) peptides. Identical immunization regimens were  
10        used for both experiments. In experiment 1 (Panel A), three codon optimized nef constructs were tested, namely, V1Jns/nef, V1Jns/tpanef(LLAA) and V1Jns/nef(G2A,LLAA), whereas in experiment 2 (Panel B) all four codon optimized nef constructs were tested. The data represent means plus standard deviation of 5  
15        mice per group.

#### DETAILED DESCRIPTION OF THE INVENTION

The present invention relates to synthetic DNA molecules (also referred to herein as "nucleic acid" molecules or "polynucleotides") and associated DNA vector vaccines (also referred to herein as "polynucleotide vaccines") which elicit CTL and  
20        humoral responses upon administration to the host, including primates and especially humans. In particular, the present invention relates to DNA vector vaccines which encode various forms of HIV-1 Nef, wherein administration, intracellular delivery and expression of the HIV-1 nef gene of interest elicits a host CTL and Th response. The synthetic DNA molecules of the present invention encode codon optimized  
25        versions of wild type HIV-1 Nef, codon optimized versions of HIV-1 Nef fusion proteins, and codon optimized versions of HIV-1 Nef derivatives, including but not limited to *nef* modifications involving introduction of an amino-terminal leader sequence, removal of an amino-terminal myristylation site and/or introduction of dileucine motif mutations. In some instances the Nef-based fusion and modified  
30        proteins disclosed within this specification possess altered trafficking and/or host cell function while retaining the ability to be properly presented to the host MHC I complex. Those skilled in the art will recognize that the use of nef genes from HIV-2 strains which express Nef proteins having analogous function to HIV-1 Nef would be expected to generate immune responses analogous to those described herein for

#### HIV-1 constructs.

In order to generate a CTL response, the immunogen must be synthesized within (MHC I presentation) or introduced into cells (MHC II presentation). For intracellular synthesized immunogens, the protein is expressed and then processed into small peptides by the proteasome complex, and translocated into the endoplasmic reticulum/Golgi complex secretory pathway for eventual association with major histocompatibility complex (MHC) class I proteins. CD8<sup>+</sup> T lymphocytes recognize antigen in association with class I MHC via the T cell receptor (TCR). Activation of naive CD8<sup>+</sup> T cells into activated effector or memory cells generally requires both TCR engagement of antigen as described above as well as engagement of co-stimulatory proteins. Optimal induction of CTL responses usually requires "help" in the form of cytokines from CD4<sup>+</sup> T lymphocytes which recognize antigen associated with MHC class II molecules via TCR.

The HIV-1 genome employs predominantly uncommon codons compared to highly expressed human genes. Therefore, the nef open reading frame has been synthetically manipulated using optimal codons for human expression. As noted above, a preferred embodiment of the present invention relates to DNA molecules which comprise a HIV-1 nef open reading frame, whether encoding full length nef or a modification or fusion as described herein, wherein the codon usage has been optimized for expression in a mammal, especially a human.

In a particular embodiment of the present invention, a DNA molecule encoding HIV-1 Nef from the HIV-1 jrf1 isolate wherein the codons are optimized for expression in a mammalian system such as a human. The nucleotide sequence of the codon optimized version of HIV-1 jrf1 nef gene is disclosed herein as SEQ ID NO:1, as shown herein:

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GATCTGCCAC CATGGGCGGC AAGTGGTCCA AGAGGTCCGT GCCCGGCTGG TCCACCGTGA
GGGAGAGGAT GAGGAGGGCC GAGCCCGCCG CCGACAGGGT GAGGAGGACC GAGCCCGCCG
CCGTGGGCGT GGGCGCCGTG TCCAGGGACC TGGAGAAGCA CGGCGCCATC ACCTCCTCCA
ACACCGCCGC CACCAACGCC GACTGCGCCT GGCTGGAGGC CCAGGAGGAC GAGGAGGTGG
GCTTCCCCGT GAGGCCCCAG GTGCCCTGA GGCCCATGAC CTACAAGGGC GCCGTGGACC
TGTCCTCACTT CCTGAAGGAG AAGGGCGGCC TGGAGGGCCT GATCCACTCC CAGAAGAGGC
AGGACATCCT GGACCTGTGG GTGTACCACA CCCAGGGCTA CTCCCCGAC TGGCAGAACT
ACACCCCGG CCCCAGCATC AGGTTCCTCC TGACCTTCGG CTGGTGCTTC AAGCTGGTGC
CCGTGGAGCC CGAGAAGGTG GAGGAGGCCA ACGAGGGCGA GAACAAGTGC CTGCTGCACC

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CCATGTCCCA GCACGGCATC GAGGACCCCG AGAAGGAGGT GCTGGAGTGG AGGTTGACT  
 CCAAGCTGGC CTTCCACCAC GTGGCCAGGG AGCTGCACCC CGAGTACTAC AAGGACTGCT  
 AAAGCCCGGG C (SEQ ID NO:1).

As can be discerned from comparing native to optimized codon usage in  
 5 Figure 2A-B, the following codon usage for mammalian optimization is preferred:  
 Met (ATG), Gly (GGC), Lys (AAG), Trp (TGG), Ser (TCC), Arg (AGG), Val (GTG),  
 Pro (CCC), Thr (ACC), Glu (GAG); Leu (CTG), His (CAC), Ile (ATC), Asn (AAC),  
 Cys (TGC), Ala (GCC), Gln (CAG), Phe (TTC) and Tyr (TAC). For an additional  
 discussion relating to mammalian (human) codon optimization, see WO 97/31115  
 10 (PCT/US97/02294), which is hereby incorporated by reference.

The open reading frame for SEQ ID NO:1 above comprises an initiating  
 methionine residue at nucleotides 12-14 and a "TAA" stop codon from nucleotides  
 660-662. The open reading frame of SEQ ID NO:1 provides for a 216 amino acid  
 HIV-1 Nef protein expressed through utilization of a codon optimized DNA vaccine  
 15 vector. The 216 amino acid HIV-1 Nef (jfr1) protein is disclosed herein as SEQ ID  
 NO:2, and as follows:

Met Gly Gly Lys Trp Ser Lys Arg Ser Val Pro Gly Trp Ser Thr Val  
 Arg Glu Arg Met Arg Arg Ala Glu Pro Ala Ala Asp Arg Val Arg Arg  
 Thr Glu Pro Ala Ala Val Gly Val Gly Ala Val Ser Arg Asp Leu Glu  
 20 Lys His Gly Ala Ile Thr Ser Ser Asn Thr Ala Ala Thr Asn Ala Asp  
 Cys Ala Trp Leu Glu Ala Gln Glu Asp Glu Glu Val Gly Phe Pro Val  
 Arg Pro Gln Val Pro Leu Arg Pro Met Thr Tyr Lys Gly Ala Val Asp  
 Leu Ser His Phe Leu Lys Glu Lys Gly Gly Leu Glu Gly Leu Ile His  
 Ser Gln Lys Arg Gln Asp Ile Leu Asp Leu Trp Val Tyr His Thr Gln  
 25 Gly Tyr Phe Pro Asp Trp Gln Asn Tyr Thr Pro Gly Pro Gly Ile Arg  
 Phe Pro Leu Thr Phe Gly Trp Cys Phe Lys Leu Val Pro Val Glu Pro  
 Glu Lys Val Glu Glu Ala Asn Glu Gly Glu Asn Asn Cys Leu Leu His  
 Pro Met Ser Gln His Gly Ile Glu Asp Pro Glu Lys Glu Val Leu Glu  
 Trp Arg Phe Asp Ser Lys Leu Ala Phe His His Val Ala Arg Glu Leu  
 30 His Pro Glu Tyr Tyr Lys Asp Cys (SEQ ID NO:2).

HIV-1 Nef is a 206 amino acid cytosolic protein which associates with the  
 inner surface of the host cell plasma membrane through myristylation of Gly-2  
 (Franchini et al., 1986, *Virology* 155: 593-599). While not all possible Nef functions  
 have been elucidated, it has become clear that correct trafficking of Nef to the inner

plasma membrane promotes viral replication by altering the host intracellular environment to facilitate the early phase of the HIV-1 life cycle and by increasing the infectivity of progeny viral particles. In one aspect of the invention regarding codon-optimized, protein-modified polypeptides, either the DNA vaccine vector molecule or the HIV-1 nef construct is modified to contain a nucleotide sequence which encodes a heterologous leader peptide such that the amino terminal region of the expressed protein will contain the leader peptide. The diversity of function that typifies eukaryotic cells depends upon the structural differentiation of their membrane boundaries. To generate and maintain these structures, proteins must be transported from their site of synthesis in the endoplasmic reticulum to predetermined destinations throughout the cell. This requires that the trafficking proteins display sorting signals that are recognized by the molecular machinery responsible for route selection located at the access points to the main trafficking pathways. Sorting decisions for most proteins need to be made only once as they traverse their biosynthetic pathways since their final destination, the cellular location at which they perform their function, becomes their permanent residence. Maintenance of intracellular integrity depends in part on the selective sorting and accurate transport of proteins to their correct destinations. Defined sequence motifs exist in proteins which can act as 'address labels'. A number of sorting signals have been found associated with the cytoplasmic domains of membrane proteins. An effective induction of CTL responses often required sustained, high level endogenous expression of an antigen. In light of its diverse biological activities, vaccines composed of wild-type Nef could potentially have adverse effects on the host cells. As membrane-association via myristylation is an essential requirement for most of Nef's function, mutants lacking myristylation, by glycine-to-alanine change, change of the dileucine motif and/or by substitution with a tpa leader sequence as described herein, will be functionally defective, and therefore will have improved safety profile compared to wild-type Nef for use as an HIV-1 vaccine component.

In a preferred and exemplified embodiment of this portion of the invention, either the DNA vector or the HIV-1 nef nucleotide sequence is modified to include the human tissue-specific plasminogen activator (tPA) leader. As shown in Figure 1A-B for the DNA vector V1Jns, a DNA vector which may be utilized to practice the present invention may be modified by known recombinant DNA methodology to contain a leader signal peptide of interest, such that downstream



cloning of the modified HIV-1 protein of interest results in a nucleotide sequence which encodes a modified HIV-1 tPA/Nef protein. In the alternative, as noted above, insertion of a nucleotide sequence which encodes a leader peptide may be inserted into a DNA vector housing the open reading frame for the Nef protein of interest.

- 5 Regardless of the cloning strategy, the end result is a polynucleotide vaccine which comprises vector components for effective gene expression in conjunction with nucleotide sequences which encode a modified HIV-1 Nef protein of interest, including but not limited to a HIV-1 Nef protein which contains a leader peptide. The amino acid sequence of the human tPA leader utilized herein is as follows:

10 MDAMKRGLCCVLLCGAVFVSPSEISS (SEQ ID NO:19).

- It has been shown that myristylation of Gly-2 in conjunction with a dileucine motif in the carboxy region of the protein is essential for Nef-induced down regulation of CD4 (Aiken et al., 1994, *Cell* 76: 853-864) via endocytosis. It has also been shown that Nef expression promotes down regulation of MHCI (Schwartz et al., 15 1996, *Nature Medicine* 2(3): 338-342) via endocytosis. The present invention relates in part to DNA vaccines which encode modified Nef proteins altered in trafficking and/or functional properties. The modifications introduced into the DNA vaccines of the present invention include but are not limited to additions, deletions or substitutions to the nef open reading frame which results in the expression of a 20 modified Nef protein which includes an amino terminal leader peptide, modification or deletion of the amino terminal myristylation site, and modification or deletion of the dileucine motif within the Nef protein and which alter function within the infected host cell. Therefore, a central theme of the DNA molecules and DNA vaccines of the present invention is (1) host administration and intracellular delivery of a codon 25 optimized nef-based DNA vector vaccine; (2) expression of a modified Nef protein which is immunogenic in terms of eliciting both CTL and Th responses; and, (3) inhibiting or at least altering known early viral functions of Nef which have been shown to promote HIV-1 replication and load within an infected host.

- In another preferred and exemplified embodiment of the present invention, the 30 nef coding region is altered, resulting in a DNA vaccine which expresses a modified Nef protein wherein the amino terminal Gly-2 myristylation residue is either deleted or modified to express alternate amino acid residues.

In another preferred and exemplified embodiment of the present invention, the nef coding region is altered, resulting in a DNA vaccine which expresses a modified

Nef protein wherein the dileucine motif is either deleted or modified to express alternate amino acid residues.

Therefore, the present invention relates to an isolated DNA molecule, regardless of codon usage, which expresses a wild type or modified Nef protein as described herein, including but not limited to modified Nef proteins which comprise a deletion or substitution of Gly 2, a deletion or substitution of Leu 174 and Leu 175 and/or inclusion of a leader sequence.

The present invention also relates to a substantially purified protein expressed from the DNA polynucleotide vaccines of the present invention, especially the purified proteins set forth below as SEQ ID NOs: 2, 4, 6, and 8. These purified proteins may be useful as protein-based HIV vaccines.

In a specific embodiment of the invention as it relates DNA vaccines encoding modified forms of HIV-1, an open reading frame which encodes a Nef protein which comprises a tPA leader sequence fused to amino acid residue 6-216 of HIV-1 Nef (jfrl) is referred to herein as opt tpanef. The nucleotide sequence comprising the open reading frame of opt tpanef is disclosed herein as SEQ ID NO:3, as shown below:

CATGGATGCA ATGAAGAGAG GGCTCTGCTG TGTGCTGCTG CTGTGTGGAG CAGTCTTCGT  
TTCGCCCAGC GAGATCTCCT CCAAGAGGTC CGTGCCCGGC TGGTCCACCG TGAGGGAGAG  
GATGAGGAGG GCCGAGCCCG CCGCCGACAG GGTGAGGAGG ACCGAGCCCG CCGCCGTGGG  
20 CGTGGGCGCC GTGTCCAGGG ACCTGGAGAA GCACGGCGCC ATCACCTCCT CCAACACCGC  
CGCCACCAAC GCCGACTGCG CCTGGCTGGA GGCCAGGAG GACGAGGAGG TGGGCTTCCC  
CGTGAGGCCC CAGGTGCCCC TGAGGCCCAT GACCTACAAG GGCGCCGTGG ACCTGTCCCA  
CTTCTGAAG GAGAAGGGCG GCCTGGAGGG CCTGATCCAC TCCCAGAAGA GGCAGGACAT  
CCTGGACCTG TGGGTGTACC ACACCCAGGG CTACTTCCCC GACTGGCAGA ACTACACCCC  
25 CGGCCCCGCG ATCAGGTTCC CCCTGACCTT CGGCTGGTGC TTCAAGCTGG TGCCCGTGGA  
GCCCAGAGAAG GTGGAGGAGG CCAACGAGGG CGAGACAAC TGCCTGCTGC ACCCATGTC  
CCAGCACGGC ATCGAGGACC CCGAGAAGGA GGTGCTGGAG TGGAGGTTTC ACTCCAAGCT  
GGCCTTCCAC CACGTGGCCA GGGAGCTGCA CCCCAGTAC TACAAGGACT GCTAAAGCC  
(SEQ ID NO:3).

The open reading frame for SEQ ID NO:3 comprises an initiating methionine

residue at nucleotides 2-4 and a "TAA" stop codon from nucleotides 713-715. The open reading frame of SEQ ID NO:3 provides for a 237 amino acid HIV-1 Nef protein which comprises a tPA leader sequence fused to amino acids 6-216 of HIV-1 Nef, including the dileucine motif at amino acid residues 174 and 175. This 237

5 amino acid tPA/Nef (jfrl) fusion protein is disclosed herein as SEQ ID NO:4, and is shown as follows:

Met Asp Ala Met Lys Arg Gly Leu Cys Cys Val Leu Leu Leu Cys Gly  
Ala Val Phe Val Ser Pro Ser Glu Ile Ser Ser Lys Arg Ser Val Pro  
Gly Trp Ser Thr Val Arg Glu Arg Met Arg Arg Ala Glu Pro Ala Ala  
10 Asp Arg Val Arg Arg Thr Glu Pro Ala Ala Val Gly Val Gly Ala Val  
Ser Arg Asp Leu Glu Lys His Gly Ala Ile Thr Ser Ser Asn Thr Ala  
Ala Thr Asn Ala Asp Cys Ala Trp Leu Glu Ala Gln Glu Asp Glu Glu  
Val Gly Phe Pro Val Arg Pro Gln Val Pro Leu Arg Pro Met Thr Tyr  
Lys Gly Ala Val Asp Leu Ser His Phe Leu Lys Glu Lys Gly Gly Leu  
15 Glu Gly Leu Ile His Ser Gln Lys Arg Gln Asp Ile Leu Asp Leu Trp  
Val Tyr His Thr Gln Gly Tyr Phe Pro Asp Trp Gln Asn Tyr Thr Pro  
Gly Pro Gly Ile Arg Phe Pro Leu Thr Phe Gly Trp Cys Phe Lys Leu  
Val Pro Val Glu Pro Glu Lys Val Glu Glu Ala Asn Glu Gly Glu Asn  
Asn Cys Leu Leu His Pro Met Ser Gln His Gly Ile Glu Asp Pro Glu  
20 Lys Glu Val Leu Glu Trp Arg Phe Asp Ser Lys Leu Ala Phe His His  
Val Ala Arg Glu Leu His Pro Glu Tyr Tyr Lys Asp Cys (SEQ ID NO:4).

Therefore, this exemplified Nef protein, Opt tPA-Nef, contains both a tPA leader sequence as well as deleting the myristylation site of Gly-2A DNA molecule encoding HIV-1 Nef from the HIV-1 jfrl isolate wherein the codons are optimized for  
25 expression in a mammalian system such as a human.

In another specific embodiment of the present invention, a DNA molecule is disclosed which encodes optimized HIV-1 Nef wherein the open reading frame codes for modifications at the amino terminal myristylation site (Gly-2 to Ala-2) and substitution of the Leu-174-Leu-175 dileucine motif to Ala-174-Ala-175. This open  
30 reading frame is herein described as opt nef (G2A,LLAA) and is disclosed as SEQ ID NO:5, which comprises an initiating methionine residue at nucleotides 12-14 and a "TAA" stop codon from nucleotides 660-662. The nucleotide sequence of this codon optimized version of HIV-1 jfrl nef gene with the above mentioned modifications is disclosed herein as SEQ ID NO:5, as follows:

GATCTGCCAC CATGGCCGGC AAGTGGTCCA AGAGGTCCGT GCCCGGCTGG TCCACCGTGA  
 GGGAGAGGAT GAGGAGGGCC GAGCCCGCCG CCGACAGGGT GAGGAGGACC GAGCCCGCCG  
 CCGTGGGCGT GGGCGCCGTG TCCAGGGACC TGGAGAAGCA CGGCGCCATC ACCTCTCCA  
 ACACCGCCGC CACCAACGCC GACTGCGCCT GGCTGGAGGC CCAGGAGGAC GAGGAGGTGG  
 5 GCTTCCCGGT GAGGCCCCAG GTGCCCTGA GGCCCATGAC CTACAAGGGC GCCGTGGACC  
 TGTCCTACTT CCTGAAGGAG AAGGGCGGCC TGGAGGGCCT GATCCACTCC CAGAAGAGGC  
 AGGACATCCT GGACCTGTGG GTGTACCACA CCCAGGGCTA CTTCCCCGAC TGGCAGAACT  
 ACACCCCCGG CCCCAGCATC AGGTCCCCC TGACCTTCGG CTGGTGCTTC AAGCTGGTGC  
 CCGTGGAGCC CGAGAAGGTG GAGGAGGCCA ACGAGGGCGA GAACAACCTGC GCCGCCACCC  
 10 CCATGTCCCA GCACGGCATC GAGGACCCCG AGAAGGAGGT GCTGGAGTGG AGGTTGACT  
 CCAAGCTGGC CTTCCACCAC GTGGCCAGGG AGCTGCACCC CGAGTACTAC AAGGACTGCT  
 AAAGCCCCGG C (SEQ ID NO:5).

The open reading frame of SEQ ID NO:5 encodes Nef (G2A,LLAA), disclosed herein as SEQ ID NO:6, as follows:

15 Met Ala Gly Lys Trp Ser Lys Arg Ser Val Pro Gly Trp Ser Thr Val  
 Arg Glu Arg Met Arg Arg Ala Glu Pro Ala Ala Asp Arg Val Arg Arg  
 Thr Glu Pro Ala Ala Val Gly Val Gly Ala Val Ser Arg Asp Leu Glu  
 Lys His Gly Ala Ile Thr Ser Ser Asn Thr Ala Ala Thr Asn Ala Asp  
 Cys Ala Trp Leu Glu Ala Gln Glu Asp Glu Glu Val Gly Phe Pro Val  
 20 Arg Pro Gln Val Pro Leu Arg Pro Met Thr Tyr Lys Gly Ala Val Asp  
 Leu Ser His Phe Leu Lys Glu Lys Gly Gly Leu Glu Gly Leu Ile His  
 Ser Gln Lys Arg Gln Asp Ile Leu Asp Leu Trp Val Tyr His Thr Gln  
 Gly Tyr Phe Pro Asp Trp Gln Asn Tyr Thr Pro Gly Pro Gly Ile Arg  
 Phe Pro Leu Thr Phe Gly Trp Cys Phe Lys Leu Val Pro Val Glu Pro  
 25 Glu Lys Val Glu Glu Ala Asn Glu Gly Glu Asn Asn Cys Ala Ala His  
 Pro Met Ser Gln His Gly Ile Glu Asp Pro Glu Lys Glu Val Leu Glu  
 Trp Arg Phe Asp Ser Lys Leu Ala Phe His His Val Ala Arg Glu Leu  
 His Pro Glu Tyr Tyr Lys Asp Cys Ser (SEQ ID NO:6).

30 An additional embodiment of the present invention relates to another DNA  
 molecule encoding optimized HIV-1 Nef wherein the amino terminal myristylation  
 site and dileucine motif have been deleted, as well as comprising a tPA leader peptide.  
 This DNA molecule, opt tpanef (LLAA) comprises an open reading frame which  
 encodes a Nef protein containing a tPA leader sequence fused to amino acid residue  
 6-216 of HIV-1 Nef (jfrl), wherein Leu-174 and Leu-175 are substituted with Ala-174

and Ala-175 (Ala-195 and Ala-196 in this tPA-based fusion protein). The nucleotide sequence comprising the open reading frame of opt tpanef (LLAA) is disclosed herein as SEQ ID NO:7, as shown below:

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CATGGATGCA ATGAAGAGAG GGCTCTGCTG TGTGCTGCTG CTGTGTGGAG CAGTCTTCGT
5  TTCGCCCAGC GAGATCTCCT CCAAGAGGTC CGTGCCCGGC TGGTCCACCG TGAGGGAGAG
   GATGAGGAGG GCCGAGCCCC CCGCCGACAG GGTGAGGAGG ACCGAGCCCC CCGCCGTGGG
   CGTGGGCGCC GTGTCCAGGG ACCTGGAGAA GCACGGCGCC ATCACCTCCT CCAACACCGC
   CGCCACCAAC GCCGACTGCG CCTGGCTGGA GGCCAGGAG GACGAGGAGG TGGGCTTCCC
   CGTGAGGCCC CAGGTGCCCC TGAGGCCCAT GACCTACAAG GGCGCCGTGG ACCTGTCCCA
10  CTTCTGAAG GAGAAGGGCG GCCTGGAGGG CCTGATCCAC TCCCAGAAGA GGCAGGACAT
   CCTGGACCTG TGGGTGTACC ACACCCAGGG CTACTTCCCC GACTGGCAGA ACTACACCCC
   CGGCCCCGGC ATCAGGTTCC CCCTGACCTT CGGCTGGTGC TTCAAGCTGG TGCCCGTGGG
   GCCCGAGAAG GTGAGGAGG CCAACGAGGG CGAGACAAC TCGCCGCCCC ACCCATGTC
   CCAGCACGGC ATCGAGGACC CCGAGAAGGA GGTGCTGGAG TGGAGGTTCT ACTCCAAGCT
15  GGCCTTCCAC CACGTGGCCA GGGAGCTGCA CCCCAGTAC TACAAGGACT GCTAAAGCCC
   (SEQ ID NO:7).

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The open reading frame of SEQ ID NO:7 encoding tPA-Nef (LLAA), disclosed herein as SEQ ID NO:8, is as follows:

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Met Asp Ala Met Lys Arg Gly Leu Cys Cys Val Leu Leu Leu Cys Gly
20  Ala Val Phe Val Ser Pro Ser Glu Ile Ser Ser Lys Arg Ser Val Pro
   Gly Trp Ser Thr Val Arg Glu Arg Met Arg Arg Ala Glu Pro Ala Ala
   Asp Arg Val Arg Arg Thr Glu Pro Ala Ala Val Gly Val Gly Ala Val
   Ser Arg Asp Leu Glu Lys His Gly Ala Ile Thr Ser Ser Asn Thr Ala
   Ala Thr Asn Ala Asp Cys Ala Trp Leu Glu Ala Gln Glu Asp Glu Glu
25  Val Gly Phe Pro Val Arg Pro Gln Val Pro Leu Arg Pro Met Thr Tyr
   Lys Gly Ala Val Asp Leu Ser His Phe Leu Lys Glu Lys Gly Gly Leu
   Glu Gly Leu Ile His Ser Gln Lys Arg Gln Asp Ile Leu Asp Leu Trp
   Val Tyr His Thr Gln Gly Tyr Phe Pro Asp Trp Gln Asn Tyr Thr Pro
   Gly Pro Gly Ile Arg Phe Pro Leu Thr Phe Gly Trp Cys Phe Lys Leu
30  Val Pro Val Glu Pro Glu Lys Val Glu Glu Ala Asn Glu Gly Glu Asn
   Asn Cys Ala Ala His Pro Met Ser Gln His Gly Ile Glu Asp Pro Glu
   Lys Glu Val Leu Glu Trp Arg Phe Asp Ser Lys Leu Ala Phe His His
   Val Ala Arg Glu Leu His Pro Glu Tyr Tyr Lys Asp Cys (SEQ ID NO:8).

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The present invention also relates in part to any DNA molecule, regardless of

codon usage, which expresses a wild type or modified Nef protein as described herein, including but not limited to modified Nef proteins which comprise a deletion or substitution of Gly 2, a deletion of substitution of Leu 174 and Leu 175 and/or inclusion of a leader sequence. Therefore, partial or fully codon optimized DNA vaccine expression vector constructs are preferred since such constructs should result in increased host expression. However, it is within the scope of the present invention to utilize "non-codon optimized" versions of the constructs disclosed herein, especially modified versions of HIV Nef which are shown to promote a substantial cellular immune response subsequent to host administration.

10 The DNA backbone of the DNA vaccines of the present invention are preferably DNA plasmid expression vectors. DNA plasmid expression vectors are well known in the art and the present DNA vector vaccines may be comprised of any such expression backbone which contains at least a promoter for RNA polymerase transcription, and a transcriptional terminator 3' to the HIV nef coding sequence. In 15 one preferred embodiment, the promoter is the Rous sarcoma virus (RSV) long terminal repeat (LTR) which is a strong transcriptional promoter. A more preferred promoter is the cytomegalovirus promoter with the intron A sequence (CMV-intA). A preferred transcriptional terminator is the bovine growth hormone terminator. In addition, to assist in large scale preparation of an HIV nef DNA vector vaccine, an 20 antibiotic resistance marker is also preferably included in the expression vector. Ampicillin resistance genes, neomycin resistance genes or any other pharmaceutically acceptable antibiotic resistance marker may be used. In a preferred embodiment of this invention, the antibiotic resistance gene encodes a gene product for neomycin resistance. Further, to aid in the high level production of the pharmaceutical by 25 fermentation in prokaryotic organisms, it is advantageous for the vector to contain an origin of replication and be of high copy number. Any of a number of commercially available prokaryotic cloning vectors provide these benefits. In a preferred embodiment of this invention, these functionalities are provided by the commercially available vectors known as pUC. It is desirable to remove non-essential DNA 30 sequences. Thus, the lacZ and lacI coding sequences of pUC are removed in one embodiment of the invention.

DNA expression vectors exemplified herein are also disclosed in PCT International Application No. PCT/US94/02751, International Publication No. WO 94/21797, hereby incorporated by reference. A first DNA expression vector

is the expression vector pnRSV, wherein the rous sarcoma virus (RSV) long terminal repeat (LTR) is used as the promoter. A second embodiment relates to plasmid V1, a mutated pBR322 vector into which the CMV promoter and the BGH transcriptional terminator is cloned. Another embodiment regarding DNA vector backbones relates to plasmid V1J. Plasmid V1J is derived from plasmid V1 and removes promoter and transcription termination elements in order to place them within a more defined context, create a more compact vector, and to improve plasmid purification yields. Therefore, V1J also contains the CMVintA promoter and (BGH) transcription termination elements which control the expression of the HIV nef-based genes disclosed herein. The backbone of V1J is provided by pUC18. It is known to produce high yields of plasmid, is well-characterized by sequence and function, and is of minimum size. The entire *lac* operon was removed and the remaining plasmid was purified from an agarose electrophoresis gel, blunt-ended with the T4 DNA polymerase, treated with calf intestinal alkaline phosphatase, and ligated to the CMVintA/BGH element. In another DNA expression vector, the ampicillin resistance gene is removed from V1J and replaced with a neomycin resistance gene, to generate V1Jneo. A DNA expression vector specifically exemplified herein is V1Jns, which is the same as V1J except that a unique Sfi1 restriction site has been engineered into the single Kpn1 site at position 2114 of V1J-neo. The incidence of Sfi1 sites in human genomic DNA is very low (approximately 1 site per 100,000 bases). Thus, this vector allows careful monitoring for expression vector integration into host DNA, simply by Sfi1 digestion of extracted genomic DNA. Another DNA expression vector for use as the backbone to the HIV-1 nef-based DNA vaccines of the present invention is V1R. In this vector, as much non-essential DNA as possible is "trimmed" from the vector to produce a highly compact vector. This vector is a derivative of V1Jns. This vector allows larger inserts to be used, with less concern that undesirable sequences are encoded and optimizes uptake by cells when the construct encoding specific influenza virus genes is introduced into surrounding tissue.

It will be evident upon review of the teaching within this specification that numerous vector/Nef antigen constructs may be generated. While the exemplified constructs (V1Jns/nef, V1Jns/tpanef, V1Jns/tpanef(LLAA) and V1Jns/(G2A,LLAA) are preferred, any number of vector/Nef antigen combinations are within the scope of the present invention, especially wild type or modified Nef proteins which comprise a deletion or substitution of Gly 2, a deletion or substitution of Leu 174 and Leu 175

and/or inclusion of a leader sequence. Therefore, the present invention especially relates to DNA vaccines and a pharmaceutically active vaccine composition which contains this DNA vector vaccine, and the use as prophylactic and/or therapeutic vaccine for host immunization, preferably human host immunization, against an HIV infection or to combat an existing HIV condition. These DNA vaccines are represented by codon optimized DNA molecules encoding HIV-1 Nef of biologically active Nef modifications or Nef-containing fusion proteins which are ligated within an appropriate DNA plasmid vector, with or without a nucleotide sequence encoding a functional leader peptide. DNA vaccines of the present invention include but in no way are limited to codon optimized DNA molecules encoding HIV-1 Nef of biologically active Nef modifications or Nef-containing fusion proteins ligated in DNA vectors VI, VIJ (SEQ ID NO:14), VIJneo (SEQ ID NO:15), VIJns (Figure 1A, SEQ ID NO:16), VIR (SEQ ID NO:26), or any of the aforementioned vectors wherein a nucleotide sequence encoding a leader peptide, preferably the human tPA leader, is fused directly downstream of the CMV-intA promoter, including but not limited to VIJns-tpa, as shown in Figure 1B and SEQ ID NO:19. Especially preferred DNA vaccines of the present invention include as VIJns/nef, VIJns/tpanef, VIJns/tpanef(LLAA) and VIJns/(G2A,LLAA), as exemplified in Example Section 2.

The DNA vector vaccines of the present invention may be formulated in any pharmaceutically effective formulation for host administration. Any such formulation may be, for example, a saline solution such as phosphate buffered saline (PBS). It will be useful to utilize pharmaceutically acceptable formulations which also provide long-term stability of the DNA vector vaccines of the present invention. During storage as a pharmaceutical entity, DNA plasmid vaccines undergo a physiochemical change in which the supercoiled plasmid converts to the open circular and linear form. A variety of storage conditions (low pH, high temperature, low ionic strength) can accelerate this process. Therefore, the removal and/or chelation of trace metal ions (with succinic or malic acid, or with chelators containing multiple phosphate ligands) from the DNA plasmid solution, from the formulation buffers or from the vials and closures, stabilizes the DNA plasmid from this degradation pathway during storage. In addition, inclusion of non-reducing free radical scavengers, such as ethanol or glycerol, are useful to prevent damage of the DNA plasmid from free radical production that may still occur, even in apparently demetalated solutions. Furthermore, the buffer type, pH, salt concentration, light exposure, as well as the



type of sterilization process used to prepare the vials, may be controlled in the formulation to optimize the stability of the DNA vaccine. Therefore, formulations that will provide the highest stability of the DNA vaccine will be one that includes a demetalated solution containing a buffer (phosphate or bicarbonate) with a pH in the range of 7-8, a salt (NaCl, KCl or LiCl) in the range of 100-200 mM, a metal ion  
5 chelator (e.g., EDTA, diethylenetriaminepenta-acetic acid (DTPA), malate, inositol hexaphosphate, tripolyphosphate or polyphosphoric acid), a non-reducing free radical scavenger (e.g. ethanol, glycerol, methionine or dimethyl sulfoxide) and the highest appropriate DNA concentration in a sterile glass vial, packaged to protect the highly  
10 purified, nuclease free DNA from light. A particularly preferred formulation which will enhance long term stability of the DNA vector vaccines of the present invention would comprise a Tris-HCl buffer at a pH from about 8.0 to about 9.0; ethanol or glycerol at about 3% w/v; EDTA or DTPA in a concentration range up to about 5 mM; and NaCl at a concentration from about 50 mM to about 500 mM. The use of  
15 such stabilized DNA vector vaccines and various alternatives to this preferred formulation range is described in detail in PCT International Application No. PCT/US97/06655, PCT International Publication No. WO 97/40839, which is hereby incorporated by reference.

The DNA vector vaccines of the present invention may, in addition to  
20 generating a strong CTL-based immune response, provide for a measurable humoral response subsequent immunization. This response may occur with or without the addition of adjuvant to the respective vaccine formulation. To this end, the DNA vector vaccines of the present invention may also be formulated with an adjuvant or adjuvants which may increase immunogenicity of the DNA  
25 polynucleotide vaccines of the present invention. A number of these adjuvants are known in the art and are available for use in a DNA vaccine, including but not limited to particle bombardment using DNA-coated gold beads, co-administration of DNA vaccines with plasmid DNA expressing cytokines, chemokines, or costimulatory molecules, formulation of DNA with cationic lipids or with  
30 experimental adjuvants such as saponin, monophosphoryl lipid A or other compounds which increase immunogenicity of the DNA vaccine. One preferred adjuvant for use in the DNA vector vaccines of the present invention are one or more forms of an aluminum phosphate-based adjuvant. Aluminum phosphate is known in the art for use with live, killed or subunit vaccines, but is only recently

disclosed as a useful adjuvant in DNA vaccine formulations. The artisan may alter the ratio of DNA to aluminum phosphate to provide for an optimal immune response. In addition, the aluminum phosphate-based adjuvant possesses a molar  $\text{PO}_4/\text{Al}$  ratio of approximately 0.9, and may again be altered by the skilled artisan to provide for an optimal immune response. An additional mineral-based adjuvant may be generated from one or more forms of a calcium phosphate. These mineral-based adjuvants are useful in increasing humoral responses to DNA vaccination without imparting a negative effect on an appropriate cellular immune response. Complete guidance for use of these mineral-based compounds for use as DNA vaccines adjuvants are disclosed in PCT International Application No. PCT/US98/02414, PCT International Publication No. WO 98/35562, which are hereby incorporated by reference in their entirety. Another preferred adjuvant is a non-ionic block copolymer which shows adjuvant activity with DNA vaccines. The basic structure comprises blocks of polyoxyethylene (POE) and polyoxypropylene (POP) such as a POE-POP-POE block copolymer. Newman et al. (1998, *Critical Reviews in Therapeutic Drug Carrier Systems* 15(2): 89-142) review a class of non-ionic block copolymers which show adjuvant activity. The basic structure comprises blocks of polyoxyethylene (POE) and polyoxypropylene (POP) such as a POE-POP-POE block copolymer. Newman et al. *id.*, disclose that certain POE-POP-POE block copolymers may be useful as adjuvants to an influenza protein-based vaccine, namely higher molecular weight POE-POP-POE block copolymers containing a central POP block having a molecular weight of over about 9000 daltons to about 20,000 daltons and flanking POE blocks which comprise up to about 20% of the total molecular weight of the copolymer (see also U.S. Reissue Patent No. 36,665, U.S. Patent No. 5,567,859, U.S. Patent No. 5,691,387, U.S. Patent No. 5,696,298 and U.S. Patent No. 5,990,241, all issued to Emanuele, et al., regarding these POE-POP-POE block copolymers). WO 96/04932 further discloses higher molecular weight POE/POP block copolymers which have surfactant characteristics and show biological efficacy as vaccine adjuvants. The above cited references within this paragraph are hereby incorporated by reference in their entirety. It is therefore within the purview of the skilled artisan to utilize available adjuvants which may increase the immune response of the polynucleotide vaccines of the present invention in comparison to administration of a non-adjuvanted polynucleotide vaccine.

The DNA vector vaccines of the present invention are administered to the host by any means known in the art, such as enteral and parenteral routes. These routes of delivery include but are not limited to intramuscular injection, intraperitoneal injection, intravenous injection, inhalation or intranasal delivery, oral delivery, sublingual  
5 administration, subcutaneous administration, transdermal administration, transcutaneous administration, percutaneous administration or any form of particle bombardment, such as a biolistic device such as a "gene gun" or by any available needle-free injection device. The preferred methods of delivery of the HIV-1 Nef-based DNA vaccines disclosed herein are intramuscular injection and needle-free  
10 injection. An especially preferred method is intramuscular delivery.

The amount of expressible DNA to be introduced to a vaccine recipient will depend on the strength of the transcriptional and translational promoters used in the DNA construct, and on the immunogenicity of the expressed gene product. In general, an immunologically or prophylactically effective dose of about 1  $\mu$ g to  
15 greater than about 20 mg, and preferably in doses from about 1 mg to about 5 mg is administered directly into muscle tissue. As noted above, subcutaneous injection, intradermal introduction, impression through the skin, and other modes of administration such as intraperitoneal, intravenous, inhalation and oral delivery are also contemplated. It is also contemplated that booster vaccinations are to be  
20 provided in a fashion which optimizes the overall immune response to the Nef-based DNA vector vaccines of the present invention.

The aforementioned polynucleotides, when directly introduced into a vertebrate *in vivo*, express the respective HIV-1 Nef protein within the animal and in turn induce a cytotoxic T lymphocyte (CTL) response within the host to the expressed  
25 Nef antigen. To this end, the present invention also relates to methods of using the HIV-1 Nef-based polynucleotide vaccines of the present invention to provide effective immunoprophylaxis, to prevent establishment of an HIV-1 infection following exposure to this virus, or as a post-HIV infection therapeutic vaccine to mitigate the acute HIV-1 infection so as to result in the establishment of a lower virus  
30 load with beneficial long term consequences. As noted above, the present invention contemplates a method of administration or use of the DNA nef-based vaccines of the present invention using any of the known routes of introducing polynucleotides into living tissue to induce expression of proteins.

Therefore, the present invention provides for methods of using a DNA nef-

based vaccine utilizing the various parameters disclosed herein as well as any additional parameters known in the art, which, upon introduction into mammalian tissue induces *in vivo*, intracellular expression of these DNA nef-based vaccines. This intracellular expression of the Nef-based immunogen induces a CTL and humoral response which provides a substantial level of protection against an existing HIV-1 infection or provides a substantial level of protection against a future infection in a presently uninfected host.

The following examples are provided to illustrate the present invention without, however, limiting the same hereto.

10

### EXAMPLE 1

#### Vaccine Vectors

VI – Vaccine vector VI was constructed from pCMVIE-AKI-DHFR (Whang et al., 1987, *J. Virol.* 61: 1796). The AKI and DHFR genes were removed by cutting the vector with EcoRI and self-ligating. This vector does not contain intron A in the CMV promoter, so it was added as a PCR fragment that had a deleted internal SacI site [at 1855 as numbered in Chapman, et al., (1991, *Nuc. Acids Res.* 19: 3979)]. The template used for the PCR reactions was pCMVintA-Lux, made by ligating the HindIII and NheI fragment from pCMV6a120 (see Chapman et al., *ibid.*), which includes hCMV-IE1 enhancer/promoter and intron A, into the HindIII and XbaI sites of pBL3 to generate pCMVintBL. The 1881 base pair luciferase gene fragment (HindIII-SmaI Klenow filled-in) from RSV-Lux (de Wet et al., 1987, *Mol. Cell Biol.* 7: 725) was ligated into the Sall site of pCMVintBL, which was Klenow filled-in and phosphatase treated. The primers that spanned intron A are: 5' primer: 5'-CTATATAAGCAGAGCTCGTTTAG-3' (SEQ ID NO:10); 3' primer: 5'-GTAGCAAAGATCTAAGGACGGTGACTGCAG-3' (SEQ ID NO:11). The primers used to remove the SacI site are: sense primer, 5'-GTATGTGTCTG AAAATGAGC GTGGAGATTGGGCTCGCAC-3' (SEQ ID NO:12) and the antisense primer, 5'-GTGCGAGCCCAATCTCCACGCTCATTTTCAGAC ACATAC-3' (SEQ ID NO:13). The PCR fragment was cut with Sac I and Bgl II and inserted into the vector which had been cut with the same enzymes.

VII – Vaccine vector VII was generated to remove the promoter and transcription termination elements from vector VI in order to place them within a more defined context, create a more compact vector, and to improve plasmid

purification yields. VIJ is derived from vectors V1 and pUC18, a commercially available plasmid. V1 was digested with SspI and EcoRI restriction enzymes producing two fragments of DNA. The smaller of these fragments, containing the CMVintA promoter and Bovine Growth Hormone (BGH) transcription termination elements which control the expression of heterologous genes, was purified from an agarose electrophoresis gel. The ends of this DNA fragment were then "blunted" using the T4 DNA polymerase enzyme in order to facilitate its ligation to another "blunt-ended" DNA fragment. pUC18 was chosen to provide the "backbone" of the expression vector. It is known to produce high yields of plasmid, is well-characterized by sequence and function, and is of small size. The entire *lac* operon was removed from this vector by partial digestion with the HaeII restriction enzyme. The remaining plasmid was purified from an agarose electrophoresis gel, blunt-ended with the T4 DNA polymerase treated with calf intestinal alkaline phosphatase, and ligated to the CMVintA/BGH element described above. Plasmids exhibiting either of two possible orientations of the promoter elements within the pUC backbone were obtained. One of these plasmids gave much higher yields of DNA in *E. coli* and was designated VIJ. This vector's structure was verified by sequence analysis of the junction regions and was subsequently demonstrated to give comparable or higher expression of heterologous genes compared with V1. The nucleotide sequence of VIJ is as follows:

```

TCGCGCGTTT CGGTGATGAC GGTGAAAACC TCTGACACAT GCAGCTCCCG GAGACGGTCA
CAGCTTGTCT GTAAGCGGAT GCCGGGAGCA GACAAGCCCG TCAGGGCGCG TCAGCGGGTG
TTGGCGGGTG TCGGGGCTGG CTTAACTATG CGGCATCAGA GCAGATTGTA CTGAGAGTGC
ACCATATGCG GTGTGAAATA CCGCACAGAT GCGTAAGGAG AAAATACCGC ATCAGATTGG
25 CTATTGGCCA TTGCATACGT TGTATCCATA TCATAATATG TACATTTATA TTGGCTCATG
TCCAACATTA CCGCCATGTT GACATTGATT ATTGACTAGT TATTAATAGT AATCAATTAC
GGGGTCATTA GTTCATAGCC CATATATGGA GTTCCGCGTT ACATAACTTA CGGTAAATGG
CCCGCCTGGC TGACCGCCCA ACGACCCCGG CCCATTGACG TCAATAATGA CGTATGTTCC
CATAGTAACG CCAATAGGGA CTTTCCATTG ACGTCAATGG GTGGAGTATT TACGGTAAAC
30 TGCCCACTTG GCAGTACATC AAGTGTATCA TATGCCAAGT ACGCCCCCTA TTGACGTCAA
TGACGGTAAA TGGCCCGCCT GGCATTATGC CCAGTACATG ACCTTATGGG ACTTTCCTAC
TTGGCAGTAC ATCTACGTAT TAGTCATCGC TATTACCATG GTGATGCGGT TTTGGCAGTA
CATCAATGGG CGTGGATAGC GGTTTGACTC ACGGGGATTT CCAAGTCTCC ACCCCATTGA
CGTCAATGGG AGTTTGTTTT GGCACCAAAA TCAACGGGAC TTTCCAAAAT GTCGTAACAA

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CTCCGCCCA TTGACGCAAA TGGGCGGTAG GCGGTGTACGG TGGGAGGTCT ATATAAGCAG  
AGCTCGTTTA GTGAACCGTC AGATCGCCTG GAGACGCCAT CCACGCTGTT TTGACCTCCA  
TAGAAGACAC CGGGACCGAT CCAGCCTCCG CGGCCGGGAA CGGTGCATTG GAACGCGGAT  
TCCCCGTGCC AAGAGTGACG TAAGTACCGC CTATAGAGTC TATAGGCCCA CCCCCTTGGC  
5 TTCTTATGCA TGCTATACTG TTTTGGCTT GGGGTCTATA CACCCCCGCT TCCTCATGTT  
ATAGGTGATG GTATAGCTTA GCCTATAGGT GTGGGTATT GACCATTATT GACCACTCCC  
CTATTGGTGA CGATACTTTC CATTACTAAT CCATAACATG GCTCTTTGCC ACAACTCTCT  
TTATTGGCTA TATGCCAATA CACTGTCCTT CAGAGACTGA CACGGACTCT GTATTTTAC  
AGGATGGGGT CTCATTTATT ATTTACAAAT TCACATATAC AACACCACCG TCCCAGTGC  
10 CCGCAGTTT TATTAACAT AACGTGGGAT CTCCACGCGA ATCTCGGTA CGTGTCCGG  
ACATGGGCTC TTCTCCGGTA GCGGCGGAGC TTCTACATCC GAGCCCTGCT CCCATGCCTC  
CAGCGACTCA TGGTCGCTCG GCAGCTCCTT GCTCCTAACA GTGGAGGCCA GACTTAGGCA  
CAGCACGATG CCCACCACCA CCAGTGTGCC GCACAAGGCC GTGGCGGTAG GGTATGTGTC  
TGAAAATGAG CTCGGGAGC GGGCTTGAC CGCTGACGCA TTTGGAAGAC TTAAGGCAGC  
15 GGCAGAAGAA GATGCAGGCA GCTGAGTTGT TGTGTTCTGA TAAGAGTCAG AGGTAATCC  
CGTTGCGGTG CTGTTAACGG TGGAGGGCAG TGTAGTCTGA GCAGTACTCG TTGCTGCCGC  
GCGCGCCACC AGACATAATA GCTGACAGAC TAACAGACTG TTCCTTTCCA TGGGTCTTTT  
CTGCAGTCAC CGTCCTAGA TCTGCTGTGC CTTCTAGTTG CCAGCCATCT GTGTTTGCC  
CCTCCCCCGT GCCTTCCTTG ACCCTGGAAG GTGCCACTCC CACTGTCCTT TCCTAATAAA  
20 ATGAGGAAAT TGCATCGCAT TGTCTGAGTA GGTGTCATT CATTCTGGG GGTGGGTGG  
GGCAGCACAG CAAGGGGAG GATTGGGAAG ACAATAGCAG GCATGCTGGG GATGCGGTGG  
GCTCTATGGG TACCCAGGTG CTGAAGAATT GACCCGGTTC CTCCTGGGCC AGAAAGAAGC  
AGGCACATCC CCTTCTCTGT GACACACCCT GTCCACGCC CTGGTTCTTA GTTCCAGCCC  
CACTCATAGG ACACTCATAG CTCAGGAGGG CTCCGCCTTC AATCCCACCC GCTAAAGTAC  
25 TTGGAGCGGT CTCTCCCTCC CTCATCAGCC CACCAAACCA AACCTAGCCT CCAAGAGTGG  
GAAGAAATTA AAGCAAGATA GGCTATTAAG TGCAGAGGGA GAGAAAATGC CTCCAACATG  
TGAGGAAGTA ATGAGAGAAA TCATAGAATT TCTTCCGCTT CCTCGCTCAC TGA CTGCTG  
CGCTCGGTG TTCTGGCTGCG GCGAGCGGTA TCAGCTCACT CAAAGGCGGT AATACGGTTA  
TCCACAGAAT CAGGGGATAA CGCAGGAAAG AACATGTGAG CAAAAGGCCA GCAAAAGGCC  
30 AGGAACCGTA AAAAGGCCG GTTGCTGGCG TTTTCCATA GGCTCCGCCC CCTGACGAG  
CATCACAAAA ATCGACGCTC AAGTCAGAGG TGGCGAAACC CGACAGGACT ATAAAGATAC  
CAGGCGTTTC CCCCTGGAAG CTCCCTCGTG CGCTCTCTG TTCCGACCCT GCCGCTTACC  
GGATACCTGT CCGCCTTTCT CCCTTCGGGA AGCGTGGCGC TTTCTCAATG CTCACGCTGT  
AGGTATCTCA GTTCGGTGTA GGTGTTTCG TCCAAGCTGG GCTGTGTGCA CGAACCCCC

GTTCAGCCCG ACCGCTGCGC CTTATCCGGT AACTATCGTC TTGAGTCCAA CCCGGTAAGA  
 CACGACTTAT CGCCACTGGC AGCAGCCACT GGTAACAGGA TTAGCAGAGC GAGGTATGTA  
 GGCGGTGCTA CAGAGTTCTT GAAGTGGTGG CCTAACTACG GCTACACTAG AAGGACAGTA  
 TTTGGTATCT GCGCTCTGCT GAAGCCAGTT ACCTTCGGAA AAAGAGTTGG TAGCTCTTGA  
 5 TCCGGCAAAC AAACCACCGC TGGTAGCGGT GGTTTTTTTG TTTGCAAGCA GCAGATTACG  
 CGCAGAAAAA AAGGATCTCA AGAAGATCCT TTGATCTTTT CTACGGGGTC TGACGCTCAG  
 TGGAACGAAA ACTCACGTTA AGGGATTTTG GTCATGAGAT TATCAAAAAG GATCTTCACC  
 TAGATCCTTT TAAATTAAAA ATGAAGTTTT AAATCAATCT AAAGTATATA TGAGTAACT  
 TGGCTGACA GTTACCAATG CTTAATCAGT GAGGCACCTA TCTCAGCGAT CTGTCTATTT  
 10 CGTTCATCCA TAGTTGCCGT ACTCCCCGTC GTGTAGATAA CTACGATACG GGAGGGCTTA  
 CCATCTGGCC CCACTGCTGC AATGATACCG CGAGACCCAC GCTCACCAGC TCCAGATTTA  
 TCAGCAATAA ACCAGCCAGC CGGAAGGGCC GAGCGCAGAA GTGGTCTGCG AACTTTATCC  
 GCCTCCATCC AGTCTATTAA TTGTTGCCGG GAAGCTAGAG TAAGTAGTTC GCCAGTTAAT  
 AGTTTGCGCA ACGTTGTTGC CATTGCTACA GGCATCGTGG TGTACGCTC GTCGTTTGGT  
 15 ATGGCTTCAT TCAGCTCCGG TTCCCAACGA TCAAGGCGAG TTACATGATC CCCCATGTTG  
 TGCAAAAAAG CGGTTAGCTC CTTCCGGTCT CCGATCGTTG TCAGAAGTAA GTTGGCCGCA  
 GTGTATCAC TCATGGTTAT GGCAGCACTG CATAATTCTC TTACTGTCAT GCCATCCGTA  
 AGATGCTTTT CTGTGACTGG TGAGTACTCA ACCAAGTCAT TCTGAGAATA GTGTATGCGG  
 CGACCGAGTT GCTCTTGCCC GGCCTCAATA CGGGATAATA CCGCGCCACA TAGCAGAACT  
 20 TTAAGAGTGC TCATCATTGG AAAACGTTCT TCGGGGCGAA AACTCTCAAG GATCTTACCG  
 CTGTTGAGAT CCAGTTCGAT GTAACCCACT CGTGCACCCA ACTGATCTTC AGCATCTTTT  
 ACTTTCACCA GCGTTTCTGG GTGAGCAAAA ACAGGAAGGC AAAATGCCGC AAAAAAGGGA  
 ATAAGGGCGA CACGGAATG TTGAATACTC ATACTCTTCC TTTTCAATA TTATTGAAGC  
 ATTTATCAGG GTTATTGTCT CATGAGCGGA TACATATTG AATGTATTTA GAAAAATAAA  
 25 CAAATAGGGG TTCCGCGCAC ATTTCCCCGA AAAGTGCCAC CTGACGTCTA AGAAACCATT  
 ATTATCATGA CATTAACTA TAAAAATAGG CGTATCACGA GGCCCTTTTCG TC (SEQ ID  
 NO:14).

*VII<sub>Neo</sub>* – Construction of vaccine vector *VII<sub>Neo</sub>* expression vector involved  
 removal of the *amp<sup>r</sup>* gene and insertion of the *kan<sup>r</sup>* gene (neomycin  
 30 phosphotransferase). The *amp<sup>r</sup>* gene from the pUC backbone of *VII* was removed by  
 digestion with *SspI* and *Eam110SI* restriction enzymes. The remaining plasmid was  
 purified by agarose gel electrophoresis, blunt-ended with T4 DNA polymerase, and  
 then treated with calf intestinal alkaline phosphatase. The commercially available  
*kan<sup>r</sup>* gene, derived from transposon 903 and contained within the pUC4K plasmid,

was excised using the PstI restriction enzyme, purified by agarose gel electrophoresis, and blunt-ended with T4 DNA polymerase. This fragment was ligated with the VIJ backbone and plasmids with the kan<sup>r</sup> gene in either orientation were derived which were designated as VIJneo #'s 1 and 3. Each of these plasmids was confirmed by  
5 restriction enzyme digestion analysis, DNA sequencing of the junction regions, and was shown to produce similar quantities of plasmid as VIJ. Expression of heterologous gene products was also comparable to VIJ for these VIJneo vectors. VIJneo#3, referred to as VIJneo hereafter, was selected which contains the kan<sup>r</sup> gene in the same orientation as the amp<sup>r</sup> gene in VIJ as the expression construct and  
10 provides resistance to neomycin, kanamycin and G418. The nucleotide sequence of VIJneo is as follows:

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TCGCGCGTTT CGGTGATGAC GGTGAAAACC TCTGACACAT GCAGCTCCCG GAGACGGTCA
CAGCTTGTCT GTAAGCGGAT GCCGGGAGCA GACAAGCCCG TCAGGGCGCG TCAGCGGGTG
TTGGCGGGTG TCGGGGCTGG CTTAACTATG CGGCATCAGA GCAGATTGTA CTGAGAGTGC
15 ACCATATGCG GTGTGAAATA CCGCACAGAT GCGTAAGGAG AAAATACCGC ATCAGATTGG
CTATTGGCCA TTGCATACGT TGTATCCATA TCATAATATG TACATTTATA TTGGCTCATG
TCCAACATTA CCGCCATGTT GACATTGATT ATTGACTAGT TATTAATAGT AATCAATTAC
GGGGTCATTA GTTCATAGCC CATATATGGA GTTCCGCGTT ACATAACTTA CGGTAAATGG
CCCGCCTGGC TGACCGCCCA ACGACCCCG CCCATTGACG TCAATAATGA CGTATGTTCC
20 CATAGTAACG CCAATAGGGA CTTTCCATTG ACGTCAATGG GTGGAGTATT TACGGTAAAC
TGCCCACTTG GCAGTACATC AAGTGTATCA TATGCCAAGT ACGCCCCCTA TTGACGTCAA
TGACGGTAAA TGGCCCGCCT GGCATTATGC CCAGTACATG ACCTTATGGG ACTTTCCTAC
TTGGCAGTAC ATCTACGTAT TAGTCATCGC TATTACCATG GTGATGCGGT TTTGGCAGTA
CATCAATGGG CGTGGATAGC GGTTTGACTC ACGGGGATTT CCAAGTCTCC ACCCCATTGA
25 CGTCAATGGG AGTTTGTTTT GGCACCAAAA TCAACGGGAC TTTCCAAAAT GTCGTAACAA
CTCCGCCCCA TTGACGCAAA TGGGCGGTAG GCGGTGACGG TGGGAGGTCT ATATAAGCAG
AGCTCGTTTA GTGAACCGTC AGATCGCCTG GAGACGCCAT CCACGCTGTT TTGACCTCCA
TAGAAGACAC CGGGACCGAT CCAGCCTCCG CGGCCGGGAA CGGTGCATTG GAACGCGGAT
TCCCCGTGCC AAGAGTGACG TAAGTACCGC CTATAGAGTC TATAGGCCCA CCCCCTTGCC
30 TTCTTATGCA TGCTATACTG TTTTGGCTT GGGGTCTATA CACCCCGCT TCCTCATGTT
ATAGGTGATG GTATAGCTTA GCCTATAGGT GTGGGTATT GACCATTATT GACCACTCCC
CTATTGGTGA CGATACTTTC CATTACTAAT CCATAACATG GCTCTTTGCC ACAACTCTCT
TTATTGGCTA TATGCCAATA CACTGTCCTT CAGAGACTGA CACGGACTCT GTATTTTAC
AGGATGGGGT CTCATTTATT ATTTACAAAT TCACATATAC AACACCACCG TCCCCAGTGC

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CCGCAGTTTT TATTAAACAT AACGTGGGAT CTCCACGCGA ATCTCGGGTA CGTGTTCGGG  
 ACATGGGCTC TTCTCCGGTA GCGGCGGAGC TTCTACATCC GAGCCCTGCT CCCATGCCTC  
 CAGCGACTCA TGGTCGCTCG GCAGCTCCTT GCTCCTAACA GTGGAGGCCA GACTTAGGCA  
 CAGCACGATG CCCACCACCA CCAGTGTGCC GCACAAGGCC GTGGCGGTAG GGTATGTGTC  
 5 TGAAAATGAG CTCGGGGAGC GGGCTTGCAC CGCTGACGCA TTTGGAAGAC TTAAGGCAGC  
 GGCAGAAGAA GATGCAGGCA GCTGAGTTGT TGTGTTCTGA TAAGAGTCAG AGGTAACCTC  
 CGTTGCGGTG CTGTTAACGG TGGAGGGCAG TGTAGTCTGA GCAGTACTCG TTGCTGCCGC  
 GCGCGCCACC AGACATAATA GCTGACAGAC TAACAGACTG TTCCTTTCCA TGGGTCTTTT  
 CTGCAGTCAC CGTCCTTAGA TCTGCTGTGC CTTCCTAGTTG CCAGCCATCT GTTGTTCGCC  
 10 CCTCCCCCGT GCCCTTCCTG ACCCTGGAAG GTGCCACTCC CACTGTCTTT TCCTAATAAA  
 ATGAGGAAAT TGCATCGCAT TGTCTGAGTA GGTGTCATTC TATTCTGGGG GGTGGGGTGG  
 GGCAGCACAG CAAGGGGGAG GATTGGGAAG ACAATAGCAG GCATGCTGGG GATGCGGTGG  
 GCTCTATGGG TACCCAGGTG CTGAAGAATT GACCCGGTTC CTCCTGGGCC AGAAAGAAGC  
 AGGCACATCC CCTTCTCTGT GACACACCCCT GTCCACGCCC CTGGTTCTTA GTTCCAGCCC  
 15 CACTCATAGG AACTCATAG CTCAGGAGGG CTCCGCCTTC AATCCCACCC GCTAAAGTAC  
 TTGGAGCGGT CTCTCCCTCC CTCATCAGCC CACCAAACCA AACCTAGCCT CCAAGAGTGG  
 GAAGAAATTA AAGCAAGATA GGCTATTAAG TGCAGAGGGA GAGAAATGC CTCCAACATG  
 TGAGGAAGTA ATGAGAGAAA TCATAGAATT TCTTCCGCTT CCTCGCTCAC TGACTCGCTG  
 CGCTCGGTG TTCGGCTGCG GCGAGCGGTA TCAGCTCACT CAAAGGCGGT AATACGGTTA  
 20 TCCACAGAAT CAGGGGATAA CGCAGGAAAG AACATGTGAG CAAAAGGCCA GCAAAGGCC  
 AGGAACCGTA AAAAGGCCGC GTTGCTGGCG TTTTTCATA GGCTCCGCC CCCTGACGAG  
 CATCAGAAA ATCGACGCTC AAGTCAGAGG TGGCGAAACC CGACAGGACT ATAAAGATAC  
 CAGGCGTTTC CCCCTGGAAG CTCCCTCGTG CGCTCTCCTG TTCCGACCCT GCCGCTTACC  
 GGATACCTGT CCGCCTTTCT CCCTTCGGGA AGCGTGCGC TTTCTCAATG CTCACGCTGT  
 25 AGGTATCTCA GTTCGGTGTA GGTGTTTCGC TCCAAGCTGG GCTGTGTGCA CGAACCCCCC  
 GTTCAGCCCG ACCGCTGCGC CTTATCCGGT AACTATCGTC TTGAGTCAA CCCGGTAAGA  
 CACGACTTAT CGCCACTGGC AGCAGCCACT GGTAACAGGA TTAGCAGAGC GAGGTATGTA  
 GCGGTGCTA CAGAGTTCTT GAAGTGGTGG CCTAACTACG GCTACACTAG AAGGACAGTA  
 TTTGGTATCT GCGCTCTGCT GAAGCCAGTT ACCTTCGGAA AAAGAGTTGG TAGCTCTTGA  
 30 TCCGGCAAAC AAACCACCGC TGGTAGCGGT GGTTTTTTTG TTTGCAAGCA GCAGATTACG  
 CGCAGAAAAA AAGGATCTCA AGAAGATCCT TTGATCTTTT CTACGGGGTC TGACGCTCAG  
 TGGAACGAAA ACTCACGTTA AGGGATTTTG GTCATGAGAT TATCAAAAAG GATCTTCACC  
 TAGATCCTTT TAAATTAAAA ATGAAGTTTT AAATCAATCT AAAGTATATA TGAGTAAACT  
 TGGTCTGACA GTTACCAATG CTTAATCAGT GAGGCACCTA TCTCAGCGAT CTGTCTATTT

CGTTCATCCA TAGTTGCCTG ACTCCGGGGG GGGGGGGCGC TGAGGTCTGC CTCGTGAAGA  
 AGGTGTTGCT GACTCATACC AGGCCTGAAT CGCCCCATCA TCCAGCCAGA AAGTGAGGGA  
 GCCACGGTTG ATGAGAGCTT TGTTGTAGGT GGACCAGTTG GTGATTTTGA ACTTTTGCTT  
 TGCCACGGAA CGGTCTGCGT TGTCGGGAAG ATGCGTGATC TGATCCTTCA ACTCAGCAAA  
 5 AGTTCGATTT ATTCAACAAA GCCGCCGTCC CGTCAAGTCA GCGTAATGCT CTGCCAGTGT  
 TACAACCAAT TAACCAATTC TGATTAGAAA AACTCATCGA GCATCAAATG AACTGCAAT  
 TTATTCATAT CAGGATTATC AATACCATAT TTTTGAAAAA GCCGTTTCTG TAATGAAGGA  
 GAAAACCTAC CGAGGCAGTT CCATAGGATG GCAAGATCCT GGTATCGGTC TCGGATTCCG  
 ACTCGTCAA CATCAATACA ACCTATTAAT TTCCCCTCGT CAAAAATAAG GTTATCAAGT  
 10 GAGAAATCAC CATGAGTGAC GACTGAATCC GGTGAGAATG GCAAAAGCTT ATGCATTCTT  
 TTCCAGACTT GTTCAACAGG CCAGCCATTA CGCTCGTCAT CAAATCACT CGCATCAACC  
 AAACCGTTAT TCATTCTGTA TTGCGCCTGA GCGAGACGAA ATACGCGATC GCTGTTAAAA  
 GGACAATTAC AAACAGGAAT CGAATGCAAC CGGCGCAGGA AACTGCCAG CGCATCAACA  
 ATATTTTCAC CTGAATCAGG ATATTCTTCT AATACCTGGA ATGCTGTTT CCCGGGGATC  
 15 GCAGTGGTGA GTAACCATGC ATCATCAGGA GTACGGATAA AATGCTTGAT GGTGGAAGA  
 GGCATAAATT CCGTCAGCCA GTTAGTCTG ACCATCTCAT CTGTAACATC ATTGGCAACG  
 CTACCTTTGC CATGTTTCAG AAACAACCTT GGCGCATCGG GCTTCCCATTA CAATCGATAG  
 ATTGTCGCAC CTGATTGCCC GACATTATCG CGAGCCCAT TATACCCATA TAAATCAGCA  
 TCCATGTTGG AATTTAATCG CGGCCTCGAG CAAGACGTTT CCCGTTGAAT ATGGCTCATA  
 20 ACACCCCTTG TATTACTGTT TATGTAAGCA GACAGTTTTA TTGTTTATGA TGATATATTT  
 TTATCTTG TG CAATGTAACA TCAGAGATTT TGAGACACAA CGTGGCTTTC CCCCCCCCCC  
 CATTATTGAA GCATTATCA GGGTTATTGT CTCATGAGCG GATACATATT TGAATGTATT  
 TAGAAAAATA AACAAATAGG GGTCCGCGC ACATTTCCTCC GAAAAGTGCC ACCTGACGTC  
 TAAGAAACCA TTATTATCAT GACATTAACC TATAAAAATA GGCGTATCAC GAGGCCCTTT  
 25 CGTC (SEQ ID NO:15).

30 *VIJns* - The expression vector *VIJns* was generated by adding an SfiI site to *VIJneo* to facilitate integration studies. A commercially available 13 base pair SfiI linker (New England BioLabs) was added at the KpnI site within the BGH sequence of the vector. *VIJneo* was linearized with KpnI, gel purified, blunted by T4 DNA polymerase, and ligated to the blunt SfiI linker. Clonal isolates were chosen by restriction mapping and verified by sequencing through the linker. The new vector was designated *VIJns*. Expression of heterologous genes in *VIJns* (with SfiI) was comparable to expression of the same genes in *VIJneo* (with KpnI).

The nucleotide sequence of *VIJns* is as follows:

TCGCGCGTTT CGGTGATGAC GGTGAAAACC TCTGACACAT GCAGCTCCCG GAGACGGTCA  
 CAGCTTGTCT GTAAGCGGAT GCCGGGAGCA GACAAGCCCG TCAGGGCGCG TCAGCGGGTG  
 TTGGCGGGTG TCGGGGCTGG CTTAACTATG CGGCATCAGA GCAGATTGTA CTGAGAGTGC  
 ACCATATGCG GTGTGAAATA CCGCACAGAT GCGTAAGGAG AAAATACCGC ATCAGATTGG  
 5 CTATTGGCCA TTGCATACGT TGTATCCATA TCATAATATG TACATTTATA TTGGCTCATG  
 TCCAACATTA CCGCCATGTT GACATTGATT ATTGACTAGT TATTAATAGT AATCAATTAC  
 GGGGTCATTA GTTCATAGCC CATATATGGA GTTCCGCGTT ACATAACTTA CGGTAAATGG  
 CCCGCCTGGC TGACCGCCCA ACGACCCCG CCCATTGACG TCAATAATGA CGTATGTTCC  
 CATAGTAACG CCAATAGGGA CTTTCCATTG ACGTCAATGG GTGGAGTATT TACGGTAAAC  
 10 TGCCCACTTG GCAGTACATC AAGTGTATCA TATGCCAAGT ACGCCCCCTA TTGACGTCAA  
 TGACGGTAAA TGGCCCGCCT GGCATTATGC CCAGTACATG ACCTTATGGG ACTTTCCTAC  
 TTGGCAGTAC ATCTACGTAT TAGTCATCGC TATTACCATG GTGATGCGGT TTTGGCAGTA  
 CATCAATGGG CGTGGATAGC GGTTTGACTC ACGGGGATTT CCAAGTCTCC ACCCCATTGA  
 CGTCAATGGG AGTTTGT TTTT GGCACCAAAA TCAACGGGAC TTTCCAAAAT GTCGTAACAA  
 15 CTCCGCCCCA TTGACGCAAA TGGGCGGTAG GCGTGTACGG TGGGAGGTCT ATATAAGCAG  
 AGCTCGTTTA GTGAACCGTC AGATCGCCTG GAGACGCCAT CCACGCTGTT TTGACCTCCA  
 TAGAAGACAC CGGGACCGAT CCAGCCTCCG CGGCCGGGAA CGGTGCATTG GAACGCGGAT  
 TCCCCGTGCC AAGAGTGACG TAAGTACCGC CTATAGACTC TATAGGCACA CCCCTTTGGC  
 TCTTATGCAT GCTATACTGT TTTTGGCTTG GGGCCTATAC ACCCCCGCTT CCTTATGCTA  
 20 TAGGTGATGG TATAGCTTAG CCTATAGGTG TGGGTTATTG ACCATTATTG ACCACTCCCC  
 TATTGGTGAC GATACTTTCC ATTACTAATC CATAACATGG CTCTTTGCCA CAACTATCTC  
 TATTGGCTAT ATGCCAATAC TCTGTCCTTC AGAGACTGAC ACGGACTCTG TATTTTACAA  
 GGATGGGGTC CCATTTATTA TTTACAAATT CACATATACA ACAACGCCGT CCCCCGTGCC  
 CGCAGTTTTT ATTAAACATA GCGTGGGATC TCCACGCGAA TCTCGGGTAC GTGTTCCGGA  
 25 CATGGGCTCT TCTCCGGTAG CGGCGGAGCT TCCACATCCG AGCCCTGGTC CCATGCCTCC  
 AGCGGCTCAT GGTGCTCGG CAGCTCCTTG CTCCTAACAG TGGAGGCCAG ACTTAGGCAC  
 AGCACAATGC CCACCACCAC CAGTGTGCCG CACAAGGCCG TGGCGGTAGG GTATGTGTCT  
 GAAAATGAGC GTGGAGATTG GGCTCGCACG GCTGACGCAG ATGGAAGACT TAAGGCAGCG  
 GCAGAAGAAG ATGCAGGCAG CTGAGTTGTT GTATTCTGAT AAGAGTCAGA GGTAACCTCC  
 30 GTTGCGGTGC TGTTAACGGT GGAGGGCAGT GTAGTCTGAG CAGTACTCGT TGCTGCCGCG  
 CGCGCCACCA GACATAATAG CTGACAGACT AACAGACTGT TCCTTTCCAT GGGTCTTTTC  
 TGCAGTCACC GTCCTTAGAT CTGCTGTGCC TTCTAGTTGC CAGCCATCTG TTGTTTGCCC  
 CTCCCCGTG CCTTCTTGA CCCTGGAAGG TGCCACTCCC ACTGTCCTTT CCTAATAAAA  
 TGAGGAAATT GCATCGCATT GTCTGAGTAG GTGTCAATCT ATTCTGGGGG GTGGGGTGGG

GCAGGACAGC AAGGGGGAGG ATTGGAAGA CAATAGCAGG CATGCTGGGG ATGCGGTGGG  
CTCTATGGCC GCTGCGGCCA GGTGCTGAAG AATTGACCCG GTTCCTCCTG GGCCAGAAAAG  
AAGCAGGCAC ATCCCCTTCT CTGTGACACA CCCTGTCCAC GCCCCTGGTT CTTAGTTCCA  
GCCCCACTCA TAGGACTCTC ATAGCTCAGG AGGGCTCCGC CTTCAATCCC ACCCGCTAAA  
5 GTACTTGGAG CGGTCTCTCC CTCCTCATC AGCCACCAA ACCAAACCTA GCCTCCAAGA  
GTGGGAAGAA ATTAAAGCAA GATAGGCTAT TAAGTGCAGA GGGAGAGAAA ATGCCTCCAA  
CATGTGAGGA AGTAATGAGA GAAATCATAG AATTTCTTCC GCTTCCTCGC TCACTGACTC  
GCTGCGCTCG GTCGTTCCGC TCGCGCGAGC GGTATCAGCT CACTCAAAGG CGGTAATACG  
GTTATCCACA GAATCAGGGG ATAACGCAGG AAAGAACATG TGAGCAAAAG GCCAGCAAAA  
10 GGCCAGGAAC CGTAAAAAGG CCGCGTTGCT GCGGTTTTTC CATAGGCTCC GCCCCCTGA  
CGAGCATCAC AAAAATCGAC GCTCAAGTCA GAGGTGGCGA AACCCGACAG GACTATAAAG  
ATACCAGGCG TTTCCTCCCTG GAAGCTCCCT CGTGCGCTCT CCTGTTCCGA CCCTGCGCT  
TACCGGATAC CTGTCCGCCT TTCTCCCTTC GGGAAGCGTG GCGCTTTCTC ATAGCTCAGG  
CTGTAGGTAT CTCAGTTCGG TGTAGGTCGT TCGCTCCAAG CTGGGCTGTG TGCACGAACC  
15 CCCCCTTCAG CCCGACCGCT GCGCCTTATC CGGTAAGTAT CGTCTTGAGT CCAACCCGGT  
AAGACACGAC TTATCGCCAC TGGCAGCAGC CACTGGTAAC AGGATTAGCA GAGCGAGGTA  
TGTAGGCGGT GCTACAGAGT TCTTGAAGTG GTGGCCTAAC TACGGCTACA CTAGAAGAAC  
AGTATTTGGT ATCTGCGCTC TGCTGAAGCC AGTTACCTTC GGAAAAAGAG TTGGTAGCTC  
TTGATCCGGC AAACAAACCA CCGCTGGTAG CCGTGGTTTT TTTGTTTGCA AGCAGCAGAT  
20 TACGCGCAGA AAAAAAGGAT CTCAAGAAGA TCCTTTGATC TTTTCTACGG GGTCTGACGC  
TCAGTGGAAC GAAAACTCAC GTTAAGGGAT TTTGGTCATG AGATTATCAA AAAGGATCTT  
CACCTAGATC CTTTAAATTT AAAAATGAAG TTTTAAATCA ATCTAAAGTA TATATGAGTA  
AACTTGGTCT GACAGTTACC AATGCTTAAT CAGTGAGGCA CCTATCTCAG CGATCTGTCT  
ATTTGCTTCA TCCATAGTTG CCTGACTCGG GGGGGGGGGG CGCTGAGGTC TGCCTCGTGA  
25 AGAAGGTGTT GCTGACTCAT ACCAGGCCCTG AATCGCCCCA TCATCCAGCC AGAAAGTGAG  
GGAGCCACGG TTGATGAGAG CTTTGTGTGA GGTGGACCAG TTGGTGATTT TGAACTTTTG  
CTTTGCCACG GAACGGTCTG CGTTGTTCGGG AAGATGCGTG ATCTGATCCT TCAACTCAGC  
AAAAGTTCGA TTTATTCAAC AAAGCCGCCG TCCCGTCAAG TCAGCGTAAT GCTCTGCCAG  
TGTTACAACC AATTAACCAA TTCTGATTAG AAAAATCAT CGAGCATCAA ATGAAACTGC  
30 AATTTATTCA TATCAGGATT ATCAATACCA TATTTTGTAA AAAGCCGTTT CTGTAATGAA  
GGAGAAAAC CACCGAGGCA GTTCCATAGG ATGGCAAGAT CCTGGTATCG GTCTGCGATT  
CCGACTCGTC CAACATCAAT ACAACCTATT AATTTCCCCT CGTCAAAAAT AAGGTTATCA  
AGTGAGAAAT CACCATGAGT GACGACTGAA TCCGGTGAGA ATGGCAAAAG CTTATGCATT  
TCTTTCAGA CTTGTTCAAC AGGCCAGCCA TTACGCTCGT CATCAAAATC ACTCGCATCA

ACCAAACCGT TATTCATTCG TGATTGCGCC TGAGCGAGAC GAAATACGCG ATCGCTGTTA  
 AAAGGACAAT TACAAACAGG AATCGAATGC AACCGGCGCA GGAACACTGC CAGCGCATCA  
 ACAATATTTT CACCTGAATC AGGATATTCT TCTAATACCT GGAATGCTGT TTCCCGGGG  
 ATCGCAGTGG TGAGTAACCA TGCATCATCA GGAGTACGGA TAAATGCTT GATGGTCGGA  
 5 AGAGGCATAA ATTCCGTCAG CCAGTTTAGT CTGACCATCT CATCTGTAAC ATCATTGGCA  
 ACGCTACCTT TGCCATGTTT CAGAAACAAC TCTGGCGCAT CGGGCTTCCC ATACAATCGA  
 TAGATTGTCT CACCTGATTG CCCGACATTA TCGCGAGCCC ATTTATACCC ATATAAATCA  
 GCATCCATGT TGAATTAA TCGCGGCCTC GAGCAAGACG TTCCCGTTG AATATGGCTC  
 ATAAACACCCC TTGTATTACT GTTTATGTAA GCAGACAGTT TTATTGTTCA TGATGATATA  
 10 TTTTATCTT GTGCAATGTA ACATCAGAGA TTTTGAGACA CAACGTGGCT TTCCCCCCCC  
 CCCCATTATT GAAGCATTTA TCAGGGTTAT TGTCTCATGA GCGGATACAT ATTTGAATGT  
 ATTTAGAAAA ATAAACAAAT AGGGGTTCG CGCACATTTC CCCGAAAAGT GCCACCTGAC  
 GTCTAAGAAA CCATTATTAT CATGACATTA ACCTATAAAA ATAGGCGTAT CACGAGGCC  
 TTTCGTC (SEQ ID NO:16) .

15 The underlined nucleotides of SEQ ID NO:16 represent the SfiI site introduced into the Kpn I site of VIJneo.

VIJns-tPA – The vaccine vector VIJns-tPA was constructed in order to fuse a heterologous leader peptide sequence to the nef DNA constructs of the present invention. More specifically, the vaccine vector VIJns was modified to include the
 20 human tissue-specific plasminogen activator (tPA) leader. As an exemplification, but by no means a limitation of generating a nef DNA construct comprising an amino-terminal leader sequence, plasmid VIJneo was modified to include the human tissue-specific plasminogen activator (tPA) leader. Two synthetic complementary oligomers
 25 were annealed and then ligated into VIJneo which had been BglII digested. The sense and antisense oligomers were 5' GATCACCATGGATGCAATGAAGAGAG GGCTCTGCTGTGTGCTGCTGCTGTGTGGAGCAGTCTTCGTTTCGCCCAG CGA-3' (SEQ ID NO:17); and, 5'-GATCTCGCTGGGCGAAACGAAGACTGC TCCACACAGCAGCAGCACACAGCAGAGCCCTCTCTTCATTGCATCCAT GGT-3' (SEQ ID NO:18). The Kozak sequence is underlined in the sense oligomer.
 30 These oligomers have overhanging bases compatible for ligation to BglII-cleaved sequences. After ligation the upstream BglII site is destroyed while the downstream BglII is retained for subsequent ligations. Both the junction sites as well as the entire tPA leader sequence were verified by DNA sequencing. Additionally, in order to conform with VIJns (=VIJneo with an SfiI site), an SfiI restriction site was placed at

the KpnI site within the BGH terminator region of VIJneo-tPA by blunting the KpnI site with T4 DNA polymerase followed by ligation with an SfiI linker (catalogue #1138, New England Biolabs), resulting in VIJns-tPA. This modification was verified by restriction digestion and agarose gel electrophoresis.

- 5 The VIJns-tpa vector nucleotide sequence is as follows:

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TCGCGCGTTT CGGTGATGAC GGTGAAAACC TCTGACACAT GCAGCTCCCG GAGACGGTCA
CAGCTTGTCT GTAAGCGGAT GCCGGGAGCA GACAAGCCCG TCAGGGCGCG TCAGCGGGTG
TTGGCGGGTG TCGGGGCTGG CTTAACTATG CGGCATCAGA GCAGATTGTA CTGAGAGTGC
ACCATATGCG GTGTGAAATA CCGCACAGAT GCGTAAGGAG AAAATACCGC ATCAGATTGG
10 CTATTGGCCA TTGCATACGT TGTATCCATA TCATAATATG TACATTTATA TTGGCTCATG
TCCAACATTA CCGCCATGTT GACATTGATT ATTGACTAGT TATTAATAGT AATCAATTAC
GGGGTCATTA GTTCATAGCC CATATATGGA GTTCCGCGTT ACATAACTTA CGGTAAATGG
CCCGCCTGGC TGACCGCCCA ACGACCCCG CCCATTGACG TCAATAATGA CGTATGTTC
CATAGTAACG CCAATAGGGA CTTTCCATTG ACGTCAATGG GTGGAGTATT TACGGTAAAC
15 TGCCCACTTG GCAGTACATC AAGTGTATCA TATGCCAAGT ACGCCCCCTA TTGACGTCAA
TGACGGTAAA TGGCCCGCCT GGCATTATGC CCAGTACATG ACCTTATGGG ACTTTCCTAC
TTGGCAGTAC ATCTACGTAT TAGTCATCGC TATTACCATG GTGATGCGGT TTTGGCAGTA
CATCAATGGG CGTGGATAGC GGTTTGACTC ACGGGGATTT CCAAGTCTCC ACCCCATTGA
CGTCAATGGG AGTTTGT TTTT GGCACCAAAA TCAACGGGAC TTTCCAAAAT GTCGTAACAA
20 CTCGCCCCCA TTGACGCAAA TGGGCGGTAG GCGTGTACGG TGGGAGGTCT ATATAAGCAG
AGCTCGTTTA GTGAACCGTC AGATCGCCTG GAGACGCCAT CCACGCTGTT TTGACCTCCA
TAGAAGACAC CGGGACCGAT CCAGCCTCCG CGGCCGGGAA CGGTGCATTG GAACGCGGAT
TCCCCGTGCC AAGAGTGACG TAAGTACCGC CTATAGACTC TATAGGCACA CCCCTTTGGC
TCTTATGCAT GCTATACTGT TTTTGGCTTG GGGCCTATAC ACCCCCGCTT CCTTATGCTA
25 TAGGTGATGG TATAGCTTAG CCTATAGGTG TGGGTATTG ACCATTATTG ACCACTCCCC
TATTGGTGAC GATACTTTCC ATTACTAATC CATAACATGG CTCCTTGCCA CAACTATCTC
TATTGGCTAT ATGCCAATAC TCTGTCTTC AGAGACTGAC ACGGACTCTG TATTTTACA
GGATGGGGTC CCATTTATTA TTTACAAATT CACATATACA ACAACGCCGT CCCCCGTGCC
CGCAGTTTTT ATTAAACATA GCGTGGGATC TCCACGCGAA TCTCGGGTAC GTGTTCCGGA
30 CATGGGCTCT TCTCCGGTAG CGGCGGAGCT TCCACATCCG AGCCCTGGTC CCATGCCTCC
AGCGGCTCAT GGTGCTCGG CAGCTCCTTG CTCCTAACAG TGGAGGCCAG ACTTAGGCAC
AGCACAAATGC CCACCACCAC CAGTGTGCCG CACAAGGCCG TGGCGGTAGG GTATGTGTCT
GAAAATGAGC GTGGAGATTG GGCTCGCACG GCTGACGCAG ATGGAAGACT TAAGGCAGCG
GCAGAAGAAG ATGCAGGCAG CTGAGTTGTT GTATTCTGAT AAGAGTCAGA GGTAACCTCC

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GTTGCGGTGC TGTTAACGGT GGAGGGCAGT GTAGTCTGAG CAGTACTCGT TGCTGCCCGC  
 CGCGCCACCA GACATAATAG CTGACAGACT AACAGACTGT TCCTTTCCAT GGGTCTTTTC  
 TGCAGTCACC GTCCTTAGAT CACCATGGAT GCAATGAAGA GAGGGCTCTG CTGTGTGCTG  
CTGCTGTGTG GAGCAGTCTT CGTTTCGCCC AGCGAGATCT GCTGTGCCTT CTAGTTGCCA  
 5 GCCATCTGTT GTTTGCCCCCT CCCCCGTGCC TTCCTTGACC CTGGAAGGTG CCACTCCAC  
 TGCTCTTTCC TAATAAAATG AGGAAATTGC ATCGCATTGT CTGAGTAGGT GTCAATCTAT  
 TCTGGGGGGT GGGGTGGGGC AGGACAGCAA GGGGAGGAT TGGGAAGACA ATAGCAGGCA  
 TGCTGGGGAT GCGGTGGGCT CTATGGCCGC TCGGCCCAGG TGCTGAAGAA TTGACCCGGT  
 TCCTCCTGGG CCAGAAAGAA GCAGGCACAT CCCCTTCTCT GTGACACACC CTGTCCACGC  
 10 CCCTGGTTCT TAGTTCACG CCCACTCATA GGACACTCAT AGCTCAGGAG GGCTCCGCCT  
 TCAATCCAC CCGCTAAAGT ACTTGAGCG GTCTCTCCCT CCCTCATCAG CCCACCAAC  
 CAAACCTAGC CTCCAAGAGT GGAAGAAAT TAAAGCAAGA TAGGCTATTA AGTGACAGAG  
 GAGAGAAAAT GCCTCCAACA TGTGAGGAAG TAATGAGAGA AATCATAGAA TTTCTCCGC  
 TTCTTCGCTC ACTGACTCGC TCGCTCGGT CGTTCGGCTG CGGCGAGCGG TATCAGCTCA  
 15 CTCAAAGCGG GTAATACGGT TATCCACAGA ATCAGGGGAT AACGCAGGAA AGAACATGTG  
 AGCAAAAGGC CAGCAAAAGG CCAGGAACCG TAAAAGGCC GCGTTGCTGG CGTTTTCCTCA  
 TAGGCTCCGC CCCCTGACG AGCATCACA AAATCGACGC TCAAGTCAGA GGTGGCGAAA  
 CCCGACAGGA CTATAAAGAT ACCAGGCGTT TCCCCCTGGA AGCTCCCTCG TCGCTCTCC  
 TGTTCCGACC CTGCCGCTTA CCGGATACCT GTCCGCCTTT CTCCCTTCGG GAAGCGTGGC  
 20 GCTTTCCTCAT AGCTCACGCT GTAGGTATCT CAGTTCGGTG TAGGTCGTTT GCTCCAAGCT  
 GGGCTGTGTG CACGAACCCC CCGTTCAGCC CGACCGCTGC GCCTTATCCG GTAACATCG  
 TCTTGAGTCC AACCCGGTAA GACACGACTT ATCGCCACTG GCAGCAGCCA CTGGAACAG  
 GATTAGCAGA GCGAGGTATG TAGGCGGTGC TACAGAGTTC TTGAAGTGGT GGCCTAATA  
 CGGCTACACT AGAAGAACAG TATTTGGTAT CTGCGCTCTG CTGAAGCCAG TTACCTTCGG  
 25 AAAAGAGTT GGTAGCTCTT GATCCGCAA ACAACACC GCTGGTAGCG GTGGTTTTTT  
 TGTTTGCAAG CAGCAGATTA CGCGCAGAAA AAAAGGATCT CAAGAAGATC CTTTGATCTT  
 TTCTACGGGG TCTGACGCTC AGTGAACGA AAATCACGT TAAGGGATTT TGGTCATGAG  
 ATTATCAAAA AGGATCTTCA CCTAGATCCT TTTAAATTAA AAATGAAGTT TTAATCAAT  
 CTAAGTATA TATGAGTAAA CTGGTCTGA CAGTTACCAA TGCTTAATCA GTGAGGCACC  
 30 TATCTCAGCG ATCTGTCTAT TTCGTTATC CATAGTTGCC TGACTCGGGG GGGGGGGGCG  
 CTGAGGTCTG CCTCGTGAAG AAGGTGTTGC TGACTCATAC CAGGCCTGAA TCGCCCCATC  
 ATCCAGCCAG AAAGTGAGGG AGCCACGGTT GATGAGAGCT TTGTTGTAGG TGGACCAGTT  
 GGTGATTTTG AACTTTTGCT TTGCCACGGA ACGGTCTGCG TTGTCGGGAA GATGCGTGAT  
 CTGATCCCTC AACTCAGCAA AAGTTCGATT TATCAACAA AGCCGCGCTC CCGTCAAGTC

AGCGTAATGC TCTGCCAGTG TTACAACCAA TTAACCAATT CTGATTAGAA AAACATCATCG  
 AGCATCAAAT GAAACTGCAA TTTATTTCATA TCAGGATTAT CAATACCATA TTTTGTAAAA  
 AGCCGTTTCT GTAATGAAGG AGAAACTCA CCGAGGCAGT TCCATAGGAT GGCAAGATCC  
 TGGTATCGGT CTGCGATTCC GACTCGTCCA ACATCAATAC AACCTATTAA TTTCCCTCG  
 5 TCAAAAATAA GGTATCAAG TGAGAAATCA CCATGAGTGA CGACTGAATC CGGTGAGAAT  
 GGCAAAAGCT TATGCATTTT TTTCCAGACT TGTTCACAG GCCAGCCATT ACGCTCGTCA  
 TCAAAATCAC TCGCATCAAC CAAACCGTTA TTCATTCGTG ATTGCGCCTG AGCGAGACGA  
 AATACGCGAT CGCTGTAAA AGGACAATTA CAAACAGGAA TCGAATGCAA CCGGCGCAGG  
 AACACTGCCA GCGCATCAAC AATATTTTCA CCTGAATCAG GATATTCTTC TAATACCTGG  
 10 AATGCTGTTT TCCCGGGGAT CGCAGTGGTG AGTAACCATG CATCATCAGG AGTACGGATA  
 AAATGCTTGA TGGTCGGAAG AGGCATAAAT TCCGTCAGCC AGTTTAGTCT GACCATCTCA  
 TCTGTAACAT CATGCGAAC GCTACCTTTG CCATGTTTCA GAAACAATC TGGCGCATCG  
 GGCTTCCCAT ACAATCGATA GATTGTCGCA CCTGATTGCC CGACATTATC GCGAGCCCAT  
 TTATACCCAT ATAAATCAGC ATCCATGTTG GAATTAAATC GCGGCCTCGA GCAAGACGTT  
 15 TCCCGTTGAA TATGGCTCAT AACACCCCTT GTATTACTGT TTATGTAAGC AGACAGTTTT  
 ATTGTTTCATG ATGATATATT TTTATCTTGT GCAATGTAAC ATCAGAGATT TTGAGACACA  
 ACGTGGCTTT CCCCCCCCCC CCATTATTGA AGCATTTATC AGGGTTATTG TCTCATGAGC  
 GGATACATAT TTGAATGTAT TTAGAAAAAT AAACAAATAG GGGTTCGCG CACATTTCCC  
 CGAAAAGTGC CACCTGACGT CTAAGAAACC ATTATTATCA TGACATTAAC CTATAAAAAAT  
 20 AGGCGTATCA CGAGGCCCTT TCGTC (SEQ ID NO:9).

The underlined nucleotides of SEQ ID NO:9 represent the Sfi I site introduced into the Kpn I site of V1Jneo while the underlined/italicized nucleotides represent the human tPA leader sequence.

25 *VIR* – Vaccine vector *VIR* was constructed to obtain a minimum-sized vaccine vector without unneeded DNA sequences, which still retained the overall optimized heterologous gene expression characteristics and high plasmid yields that V1J and V1Jns afford. It was determined that (1) regions within the pUC backbone comprising the *E. coli* origin of replication could be removed without affecting plasmid yield from bacteria; (2) the 3'-region of the *kan<sup>r</sup>* gene following the  
 30 kanamycin open reading frame could be removed if a bacterial terminator was inserted in its place; and, (3) ~300 bp from the 3'- half of the BGH terminator could be removed without affecting its regulatory function (following the original KpnI restriction enzyme site within the BGH element). *VIR* was constructed by using PCR to synthesize three segments of DNA from V1Jns representing the CMVintA



promoter/BGH terminator, origin of replication, and kanamycin resistance elements, respectively. Restriction enzymes unique for each segment were added to each segment end using the PCR oligomers: SspI and XhoI for CMVintA/BGH; EcoRV and BamHI for the *kan*<sup>r</sup> gene; and, BclI and SalI for the *ori*<sup>r</sup>. These enzyme sites were chosen because they allow directional ligation of each of the PCR-derived DNA segments with subsequent loss of each site: EcoRV and SspI leave blunt-ended DNAs which are compatible for ligation while BamHI and BclI leave complementary overhangs as do SalI and XhoI. After obtaining these segments by PCR each segment was digested with the appropriate restriction enzymes indicated above and then ligated together in a single reaction mixture containing all three DNA segments. The 5'-end of the *ori*<sup>r</sup> was designed to include the T2 rho independent terminator sequence that is normally found in this region so that it could provide termination information for the kanamycin resistance gene. The ligated product was confirmed by restriction enzyme digestion (>8 enzymes) as well as by DNA sequencing of the ligation junctions. DNA plasmid yields and heterologous expression using viral genes within VIR appear similar to V1Jns. The net reduction in vector size achieved was 1346 bp (V1Jns = 4.86 kb; VIR = 3.52 kb). PCR oligomer sequences used to synthesize VIR (restriction enzyme sites are underlined and identified in brackets following sequence) are as follows: (1) 5'-GGTACAAAATATTGGCTATTGGC CATTGCATACG-3' (SEQ ID NO:20) [SspI]; (2) 5'-CCACATCTCGAGGAA CCGGGTCAATTCTTCAGCACC-3' (SEQ ID NO:21) [XhoI] (for CMVintA/BGH segment); (3) 5'-GGTACAGATATCGGAAAGCCACGTTGTG TCTCAAAATC-3' (SEQ ID NO:22) [EcoRV]; (4) 5'-CACATGGATCCGTAATGCTCTGCCAGTGT TACAACC-3' (SEQ ID NO:23) [BamHI], (for kanamycin resistance gene segment)

(5) 5'-GGTACATG ATCACGTAGAAAAGATCAAAGGATCTTCTTG-3' (SEQ ID NO:24) [BclI]; (6) 5'-CCACATGTCGACCCGTAAAAAGGCCGCGTTGCTGG-3' (SEQ ID NO:25): [SalI], (for *E. coli* origin of replication).

The nucleotide sequence of vector VIR is as follows:

TCGCGCGTTT CGGTGATGAC GGTGAAAACC TCTGACACAT GCAGCTCCCG GAGACGGTCA  
 30 CAGCTTGCTCT GTAAGCGGAT GCCGGGAGCA GACAAGCCCG TCAGGGCGCG TCAGCGGGTG  
 TTGGCGGGTG TCGGGGCTGG CTTAACATATG CGGCATCAGA GCAGATTGTA CTGAGAGTGC  
 ACCATATGCG GTGTGAAATA CCGCACAGAT GCGTAAGGAG AAAATACCGC ATCAGATTGG  
 CTATTGGCCA TTGCATACGT TGTATCCATA TCATAATATG TACATTTATA TTGGCTCATG  
 TCCAACATTA CCGCCATGTT GACATTGATT ATTGACTAGT TATTAATAGT AATCAATTAC

GGGGTCATTA GTTCATAGCC CATATATGGA GTTCCGCGTT ACATAACTTA CGGTAAATGG  
CCCGCCTGGC TGACCGCCCA ACGACCCCG CCCATTGACG TCAATAATGA CGTATGTTCC  
CATAGTAACG CCAATAGGGA CTTTCCATTG ACGTCAATGG GTGGAGTATT TACGGTAAAC  
TGCCCCATTG GCAGTACATC AAGTGTATCA TATGCCAAGT ACGCCCCCTA TTGACGTCAA  
5 TGACGGTAAA TGGCCCGCCT GGCATTATGC CCAGTACATG ACCTTATGGG ACTTTCCTAC  
TTGGCAGTAC ATCTACGTAT TAGTCATCGC TATTACCATG GTGATGCGGT TTTGGCAGTA  
CATCAATGGG CGTGGATAGC GGTTTGACTC ACGGGGATTT CCAAGTCTCC ACCCCATTGA  
CGTCAATGGG AGTTTGT TTTT GGCACCAAAA TCAACGGGAC TTTCCAAAAT GTCGTAAACA  
CTCCGCCCCA TTGACGCAAA TGGGCGGTAG GCGGTGACGG TGGGAGGTCT ATATAAGCAG  
10 AGCTCGTTTA GTGAACCGTC AGATCGCCTG GAGACGCCAT CCACGCTGTT TTGACCTCCA  
TAGAAGACAC CGGGACCGAT CCAGCCTCCG CGGCCGGGAA CGGTGCATTG GAACGCGGAT  
TCCCCGTGCC AAGAGTGACG TAAGTACCGC CTATAGAGTC TATAGGCCCA CCCCCTTGGC  
TTCTTATGCA TGCTATACTG TTTTGGCTT GGGGTCTATA CCCCCCGCT TCCTCATGTT  
ATAGGTGATG GTATAGCTTA GCCTATAGGT GTGGGTATT GACCATTATT GACCACTCCC  
15 CTATTGGTGA CGATACTTTC CATTACTAAT CCATAACATG GCTCTTTGCC ACAACTCTCT  
TTATTGGCTA TATGCCAATA CACTGTCCTT CAGAGACTGA CACGGACTCT GTATTTTTAC  
AGGATGGGGT CTCATTTATT ATTTACAAAT TCACATATAC AACACCACCG TCCCCAGTGC  
CCGCAGTTTT TATTAAACAT AACGTGGGAT CTCCACGCGA ATCTCGGGTA CGTGTTCGGG  
ACATGGGCTC TTCTCCGGTA GCGGCGGAGC TTCTACATCC GAGCCCTGCT CCCATGCCTC  
20 CAGCGACTCA TGGTCGCTCG GCAGCTCCTT GCTCCTAACA GTGGAGGCCA GACTTAGGCA  
CAGCACGATG CCCACCACCA CCAGTGTGCC GCACAAGGCC GTGGCGGTAG GGTATGTGTC  
TGAAAATGAG CTCGGGGAGC GGGCTTGACG CGCTGACGCA TTTGGAAGAC TTAAGGCAGC  
GGCAGAAGAA GATGCAGGCA GCTGAGTTGT TGTGTTCTGA TAAGAGTCAG AGGTAACCTC  
CGTTGCGGTG CTGTTAACGG TGGAGGGCAG TGTAAGTCTGA GCAGTACTCG TTGCTGCCCG  
25 GCGCGCCACC AGACATAATA GCTGACAGAC TAACAGACTG TTCCTTTCCA TGGGTCTTTT  
CTGCAGTCAC CGTCCTTAGA TCTGCTGTGC CTTCTAGTTG CCAGCCATCT GTTGTTTGCC  
CCTCCCCCGT GCCTTCCTTG ACCCTGGAAG GTGCCACTCC CACTGTCCTT TCCTAATAAA  
ATGAGGAAAT TGCATCGCAT TGTCTGAGTA GGTGTCATTC TATTC'TGGG GGTGGGGTGG  
GGCAGCACAG CAAGGGGGAG GATTGGGAAG ACAATAGCAG GCATGCTGGG GATGCGGTGG  
30 GCTCTATGGG TACCCAGGTG CTGAAGAATT GACCCGGTTC CTCCTGGGCC AGAAAGAAGC  
AGGCACATCC CCTTCTCTGT GACACACCTT GTCCACGCCC CTGGTTCTTA GTTCCAGCCC  
CACTCATAGG ACACTCATAG CTCAGGAGGG CTCCGCCTTC AATCCCACCC GCTAAAGTAC  
TTGAGCGGT CTCTCCCTCC CTCATCAGCC CACCAAACCA AACCTAGCCT CCAAGAGTGG  
GAAGAAATTA AAGCAAGATA GGCTATTAAG TGCAGAGGA GAGAAAATGC CTCCAACATG

TGAGGAAGTA ATGAGAGAAA TCATAGAATT TCTTCCGCTT CCTCGCTCAC TGACTCGCTG  
CGCTCGGTCG TTCGGCTGCG GCGAGCGGTA TCAGCTCACT CAAAGGCGGT AATACGGTTA  
TCCACAGAAT CAGGGGATAA CGCAGGAAAG AACATGTGAG CAAAAGGCCA GCAAAGGCC  
AGGAACCGTA AAAAGGCCGC GTTGCTGGCG TTTTCCATA GGCTCCGCCC CCCTGACGAG  
5 CATCACAAAA ATCGACGCTC AAGTCAGAGG TGGCGAAACC CGACAGGACT ATAAAGATAC  
CAGGCGTTTC CCCCTGGAAG CTCCCTCGTG CGCTCTCCTG TTCCGACCCT GCCGCTTACC  
GGATACCTGT CCGCCTTTCT CCCTTCGGGA AGCGTGGCGC TTTCTCAATG CTCACGCTGT  
AGGTATCTCA GTTCGGTGTA GGTGCTTCGC TCCAAGCTGG GCTGTGTGCA CGAACCCCCC  
GTTACAGCCG ACCGCTGCGC CTTATCCGGT AACTATCGTC TTGAGTCCAA CCCGTAAGA  
10 CACGACTTAT CGCCACTGGC AGCAGCCACT GGTAACAGGA TTAGCAGAGC GAGGTATGTA  
GGCGGTGCTA CAGAGTTCCT GAAGTGGTGG CCTAACTACG GCTACACTAG AAGGACAGTA  
TTTGATCTCT GCGCTCTGCT GAAGCCAGTT ACCTTCGGAA AAAGAGTTGG TAGCTCTTGA  
TCCGGCAAAC AAACCACCGC TGGTAGCGGT GGTTTTTTT TTTGCAAGCA GCAGATTACG  
CGCAGAAAAA AAGGATCTCA AGAAGATCCT TTGATCTTTT CTACGGGGTC TGACGCTCAG  
15 TGGAACGAAA ACTCACGTTA AGGGATTTTG GTCATGAGAT TATCAAAAAG GATCTTCACC  
TAGATCCTTT TAAATTAAAA ATGAAGTTT AAATCAATCT AAAGTATATA TGAGTAACT  
TGGTCTGACA GTTACCAATG CTTAATCAGT GAGGCACCTA TCTCAGCGAT CTGCTATTT  
CGTTATCCA TAGTTGCCTG ACTCCGGGG GGGGGGGCGC TGAGGTCTGC CTCGTGAAGA  
AGGTGTTGCT GACTCATACC AGGCCTGAAT CGCCCATCA TCCAGCCAGA AAGTGAGGGA  
20 GCCACGGTTG ATGAGAGCTT TGTGTAGGT GGACCAGTG GTGATTTGA ACTTTTGCTT  
TGCCACGGAA CGGTCTGCGT TGTCGGGAAG ATGCGTGATC TGATCCTTCA ACTCAGCAAA  
AGTTCGATTT ATTCAACAAA GCCGCCGTCC CGTCAAGTCA GCGTAATGCT CTGCCAGTGT  
TACAACCAAT TAACCAATTC TGATTAGAAA AACTCATCGA GCATCAAATG AAAGTGAAT  
TTATTCATAT CAGGATTATC AATACCATAT TTTGAAAAA GCCGTTTCTG TAATGAAGGA  
25 GAAAACTCAC CGAGGCAGTT CCATAGGATG GCAAGATCCT GGTATCGGTC TGCGATTCCG  
ACTCGTCCAA CATCAATACA ACCTATTAAT TTCCCTCGT CAAAAATAAG GTTATCAAGT  
GAGAAATCAC CATGAGTGAC GACTGAATCC GGTGAGAATG GCAAAGCTT ATGCATTCT  
TTCCAGACTT GTTCAACAGG CCAGCCATTA CGCTCGTCAT CAAATCACT CGCATCAACC  
AAACCGTTAT TCATTGCTGA TTGCGCTGA GCGAGACGAA ATACGCGATC GCTGTTAAAA  
30 GGACAATTAC AAACAGGAAT CGAATGCAAC CGGCGCAGGA AACTGCCAG CGCATCAACA  
ATATTTTCAC CTGAATCAGG ATATTCTTCT AATACCTGGA ATGCTGTTTT CCCGGGGATC  
GCAGTGGTGA GTAACCATGC ATCATCAGGA GTACGGATAA AATGCTTGAT GGTCGGAAGA  
GGCATAAATT CCGTCAGCCA GTTTAGTCTG ACCATCTCAT CTGTAACATC ATTGGCAACG  
CTACCTTTGC CATGTTTCAG AAACAACTCT GGCGCATCGG GCTTCCATA CAATCGATAG

ATTGTCGCAC CTGATTGCCC GACATTATCG CGAGCCCATT TATACCCATA TAAATCAGCA  
 TCCATGTTGG AATTTAATCG CGGCCTCGAG CAAGACGTTT CCCGTGAAT ATGGCTCATA  
 ACACCCCTTG TATTACTGTT TATGTAAGCA GACAGTTTTA TTGTCATGA TGATATATTT  
 TTATCTTGTG CAATGTAACA TCAGAGATTT TGAGACACAA CGTGGCTTTC CCCCCCCCCC  
 5 CATTATTGAA GCATTATCA GGGTTATTGT CTCATGAGCG GATACATATT TGAATGTATT  
 TAGAAAAATA AACAAATAGG GGTTCGCGC ACATTTCGCC GAAAAGTGCC ACCTGACGTC  
 TAAGAAACCA TTATTATCAT GACATTAAAC TATAAAAATA GCGGTATCAC GAGGCCCTTT  
 CGTC (SEQ ID NO:26).

10

## EXAMPLE 2

Codon Optimized HIV-1 Nef and HIV-1 Nef Derivatives as DNA Vector Vaccines

*HIV-1 Nef Vaccine Vectors* - Codon optimized nef gene coding for wt Nef protein of HIV-1 jrf1 isolate was assembled from complementary, overlapping synthetic oligonucleotides by polymerase chain reaction (PCR). The PCR primers used were designed in such that a BglII site was included in the extension of 5' primer and an SrfI site and a BglII site in the extension of 3' primer. The PCR product was digested with BglII and cloned into BglII site of a human cytomeglovirus early promoter-based expression vector, V1Jns (Figure 1A). The proper orientation of nef fragment in the context of the expression cassette was determined by asymmetric restriction mapping. The resultant plasmid is V1Jns/nef. The 5' and 3' nucleotide sequence junctions of codon optimized V1Jns/nef are shown in Figure 3A.

The mutant nef (G2A,LLAA) was also made from synthetic oligonucleotides. To assist in cloning, a PstI site and an SrfI site were included in the extensions of 5' and 3' PCR primers, respectively. The PCR product was digested with PstI and SrfI, and cloned into the PstI and SrfI sites of V1Jns/nef, replacing the original nef with nef(G2A,LLAA) fragment. This resulted in V1Jns/nef(G2A,LLAA). The 5' and 3' nucleotide sequence junctions of codon optimized V1Jns/nef (G2A,LLAA) are shown in Figure 3B.

To construct the expression vector containing human tissue plasminogen activator leader peptide and the nef fusion gene, i.e., V1Jns/tPAnef, a truncated nef gene fragment, lacking the coding sequence for the five amino terminal residues, was first amplified by PCR using V1Jns/nef as template. Both 5' and 3' PCR primers used in this reaction contained a BglII extension. The PCR amplified fragment was then digested with BglII and cloned into BglII site of the expression vector, V1Jns/tpa

(Figure 1B). The ligation of the 3' end of tpa leader peptide coding sequence to the 5' end of the nef PCR product restored the BglII site and yielded an in-frame fusion of the two genes. The 5' and 3' nucleotide sequence junctions of codon optimized V1Jns/tPAnef are shown in Figure 3C.

5 Construction of V1Jns/tpanef(LLAA) was carried out by replacing the Bsu36-SacII fragment of V1Jns/tpanef, which contains the 3' half of the nef gene and part of the vector backbone, with the Bsu36-SacII fragment from V1Jns/nef(G2A,LLAA). The 5' and 3' nucleotide sequence junctions of codon optimized V1Jns/tpanef (LLAA) are shown in Figure 3C.

10 All the nef constructs were verified by sequencing. The amino acid junctions of these constructs is shown schematically in Figure 4.

*Transfection and protein expression* - 293 cells (adenovirus transformed human embryonic kidney cell line 293) grown at approximately 30% confluence in minimum essential medium (MEM; GIBCO, Grand Island, MD) supplemented with  
15 10% fetal bovine serum (FBS; GIBCO) in a 100 mm culture dish, were transfected with 4 ug gag expression vector, V1Jns/gag, or a mixture of 4 ug gag expression vector and 4 ug nef expression vector by Lipofectin following manufacture's protocol (GIBCO). Twelve hours post-transfection, cells were washed once with 10 ml of serum-free medium, Opti-MEM I (GIBCO) and replenished with 5 ml of Opti-MEM.  
20 Following an additional 60 hr incubation, culture supernatants and cells were collected separately and used for Western blot analysis.

*Western blot analysis* - Fifty microliter of samples were separated on a 10% SDS-polyacrylamide gel (SDS-PAGE) under reducing conditions. The proteins were blotted onto a piece of PVDF membrane, and reacted to a mixture of gag mAb (#18;  
25 Intracel, Cambridge, MA) and Nef mAbs (aa64-68, aa195-201; Advanced Biotechnologies, Columbia, MD), both at 1:2000 dilution, and horseradish peroxidase (HRP)-conjugated goat anti-rabbit IgG (Zymed, San Francisco, CA). The protein bands were visualized by ECL Western blotting detection reagents, according to the manufacture's protocol (Amersham, Arlington Heights, IL).

30 *Enzyme-linked immunosorbent assay (ELISA)* - 96-well Immulon II, round-bottom plates were coated with 50 ul of Nef protein at the concentration of 2ug/ml in bicarbonate buffer, pH 9.8., per well at 4°C overnight. Plates were washed three times with PBS containing 0.05% Tween-20 (PBST), and blocked with 5% skim milk in PBST (milk-PBST) at 24°C for 2 hr, and then incubated with serial dilutions of

testing samples in milk-PBST at 24°C for 2 hr. Plates were washed with PBST three times, and added with 50 ul of HRP-conjugated goat anti-mouse IgG (Zymed) per well and incubated at 24°C for 1 hr. This was followed by three washes, and the addition of 100 ul of 1 mg/ml ABTS [(2,2'-amino-di-(3-ethylbenzthiozoline sulfonate)] (KPL, Gaithersburg, MD) per well. After 1 hr at 24°C, plates were read at a wavelength of 405nm using an ELISA plate reader.

*Enzyme-linked spot assay (Elispot)* - Nitrocellulose membrane-backed 96 well plates (MSHA plates; Millipore, Bedford, MA) were coated with 50 ul of rat anti-mouse IFN-gamma mAb, capture antibody, (R4-6A2; PharMingen, San Diego, CA) at a concentration of 5ug/ml in PBS per well at 4°C overnight. Plates were washed three times with PBST and blocked with 10% FBS in RPMI-1640 (FBS-RPMI) at 37°C in a CO2 incubator for 2 to 4 hrs. Splenocytes were suspended in RPMI-1640 with 10% FBS at  $4 \times 10^6$  cells per ml. 100 ul cells were added to each well and plates were incubated at 37°C for 20 hrs. Each sample was tested in triplicate wells. After incubation, plates were rinsed briefly with distilled water and washed three times with PBST. Fifty ul of biotinylated rat anti-mouse IFN- $\gamma$  mAb, detecting antibody (XMG1.2; PharMingen), diluted in 1% BSA in PBST at a concentration of 2 ug/ml was then added to each well. Plates were incubated at 24°C for 2 hr, followed by washes with PBST. Fifty ul of streptavidin-conjugated alkaline phosphatase (KPL) at a dilution of 1:1000 in FBS-RPMI was added to each well. The plates were incubated at 24C for an additional one hr. Following extensive wash with BPST, 100ul BCIT/NBT substrate (KPL) was added for 15 min, and color reaction was stopped by washing the plate with tap water. Plates were air-dried and spots were counterred using a dissection microscope.

*Cytotoxic T cell (CTL) assay* - Splenocytes from immunized mouse were co-cultured with syngenic peptide-pulsed, irradiated naive splenocytes for 7 days. EL-4 cells were incubated at 37°C for 1 hr with or without 20ug/ml of a designated peptide in the presence of sodium 51Cr-chromate and used as target cells. For the assay,  $10^4$  target cells were added to a 96-well plate along with different numbers of splenocytes cells. Plates were incubated at 37°C for 4 hr. After incubation, supernatants were collected and counted in a Wallac gamma-counter. Specific lysis was calculated as  $((\text{experimental release} - \text{spontaneous release}) / (\text{maximum release} - \text{spontaneous release})) \times 100\%$ . Spontaneous release was determined by incubating target cells in

medium alone, and maximum release was determined by incubating target cells in 2.5% TritonX-100. The assay was performed with triplicate samples.

*Animal experiments* - Female mice (Charles River Laboratories, Wilmington, MA), 6 to 10 weeks old, were injected in quadriceps with 100 ul of DNA in PBS.

- 5 Two weeks after immunization, spleens from individual mice were collected and used for CTL and Elispot assays.

- Results (DNA Vector Vaccine Construction)* - The exemplified Nef protein sequence is based on HIV-1 clade B jrf1 isolate. A codon-optimized nef gene was chosen for vaccine construction and for use as the parental gene for other exemplified constructs. Figure 2A-B show the comparison of coding sequence of wt nef(jrf1) and the codon optimized nef(jrf1). Two forms of myristylation site mutations were constructed; one contains a Gly2Ala change and the other a human tissue plasminogen activator (tpa) leader sequence was fused to sixth residue, Ser, of Nef (tpanef). The dileucine motif mutation was made by introducing both Leu174Ala and Leu175Ala changes. Figure 4 shows the schematic depiction of the Nef and Nef mutants. For *in vitro* expression and *in vivo* immunogenicity studies, the nef genes were cloned into expression vector, V1Jns. The resultant plasmids containing wt nef, tpanef, tpanef with dileucine motif mutation, and nef mutant with the Gly2Ala myristylation site and dileucine motif mutations were named as V1Jns/nef, V1Jns/tpanef, V1Jns/tpanef(LLAA) and V1Jns/(G2A,LLAA), respectively.

- Results - Expression and Western blotting analysis* - To evaluate the expression of the codon optimized nef constructs, adenovirus-transformed human kidney 293 cells were cotransfected with individual nef plasmids and a gag expression vector, V1Jns/gag. 72 hours post transfection, cells and medium were collected separately and analyzed by Western blotting, using both Nef- and Gag-specific mAbs. The results are shown in Figure 5. Cells transfected with V1Jns/gag only revealed a single distinct band of approximately 55 Kd, whereas the cells cotransfected with gag and nef plasmids revealed, in addition to the 55 Kd band, a major 30 Kd band and several minor bands. This pattern is consistent with that the 55 Kd species represents Gag polypeptide and the 30 Kd and other minor species are the Nef-related products. Therefore, all the nef constructs were expressed in the transfected cells. When measured against the relatively constant Gag signal as a reference, four nef genes seem to be expressed at different levels, with the following descending order, tpanef, nef, tpanef(LLAA) and nef(G2A, LLAA). With the exception of nef(G2A,LLAA),

products of nef, tpanef, tpanef(LLAA) could be detected in both cellular and medium fractions.

- Mapping of Nef-specific CD8 and CD4 epitopes in mice* – There was no information available with respect to the properties of Nef(jrfl) in eliciting cell-mediated immune responses in mice. Therefore, to characterize immunogenicity of Nef and Nef mutants exemplified herein, CD8 and CD4 epitopes were mapped. An overlapping set of overlapping nef peptides that encompass the entire 216 aa Nef polypeptide were generated. A total 21 peptides were made, which include twenty 20mers and one 16mer. Three strains of mice, Balb/c, C3H and C57BL/6, were immunized with plasmid V1Jns/Nef; splenocytes from immunized and naive mice were isolated and assessed for Nef specific INF-gamma secreting cells (SFC) by the Elispot assay. Figure 6 shows where Elispot assays were performed against separate pools of the Nef peptides. All three strains of immunized mice responded to the Nef plasmid immunization; each developed positive Nef peptide-specific INF- $\gamma$  SFCs. Based on this, further studies were carried out with fractionated CD8 and CD4 cells against individual peptides. The results are shown in Figure 7A-C. In Balb/c mice (Figure 7A), four Nef peptides, namely, aa11-30, aa61-80, aa191-210 and aa200-216, were found to be able to induce significant numbers of CD4 SFCs. In C57BL/6 mice (Figure 7B), only one peptide, ie., aa81-100, elicited significant numbers of CD4 SFCs. Compared to Balb/c and C57BL/6 mice, C3H mice (Figure 7C) showed no dominant CD4 SFC responses with particular peptides; instead, there were modest number of SFCs in response to an array of peptides, including aa21-40, aa31-50, aa121-140 aa131-150, aa181-200 and aa191-210. With respect to CD8 cells, significant SFC responses were detected with a single peptide, ie., aa51-70, in C57BL/6 mice only.

- The results from Elispot assay suggested that Nef peptide aa51-70 contained an H-2b restricted CD8 cell epitope. In order to ascertain whether this CD8 epitope also represents the cytotoxic T cell (CTL) epitope, a conventional CTL assay was carried out. The peptide aa51-70 (Figure 8A) induced low level of specific killings only. Peptides longer than 9 amino acids of a typical CTL epitope often have lower binding affinity to MHC class I molecule. It was contemplated that the low specific killings observed with peptide aa51-70 could be potentially resulted from the low binding affinity of this 20 amino acid peptide. Therefore, two shortened peptides, namely, aa60-68 and aa58-70, were synthesized and tested in CTL assays. While the



peptide aa60-68 failed to elicit any specific killings (Figure 8B), the peptide aa58-70 exhibited a drastic increase of specific killing as compared to its longer counterpart, peptide aa61-80 (Figure 8C). For example, the percentage of specific killings induced by peptide aa58-70 at an effector/target ratio of 5 to 1 was comparable to that induced by peptide aa51-80 at an effector/target ratio of 45. Thus, between peptide aa58-70 and peptide aa51-70, the former was almost ten-fold more effective in terms of inducing Nef-specific killing. The results from CTL assay therefore confirmed that the CD8 epitope detected by the Elispot assay was indeed a CTL epitope. To further map the minimum amino acid sequence for the Nef CTL epitope, additional 5 peptides were synthesized and analyzed by Elispot assay, which mapped the CTL epitope to Nef aa58-66, as shown in Table 1.

TABLE 1

Nef peptides**		INF- $\gamma$ SFC*/10 <sup>6</sup> splenocytes
Nef58-70	TAATNADCAWLEA	85
Nef59-69	AATNADCAWLE	1
Nef58-68	TAATNADCAWL	69
Nef58-67	TAATNADCAW	66
Nef58-66	TAATNADCA	92
Medium		1

\* Average of duplicate samples.

15 \*\* Amino acid sequence of all peptides contained within SEQ ID NO:2.

*Results (Evaluation of Immunogenicity of nef Mutants in Mice)* - Having identified H-2b restricted CTL and CD4 cell epitopes, the immunogenicity of the different codon optimized nef constructs in C57BL/6 mice was examined. This was performed in two separate experiments with identical immunization regimens. The first experiment involved nef, tpanef(LLAA) and nef(G2A,LLAA) and the second experiment involved nef, tpanef, tpanef(LLAA) and nef(G2A,LLAA). Mice were immunized with plasmids containing these respective codon optimized nef genes. Two weeks post immunization, splenocytes from individual mice were isolated and analyzed by Elispot assay for Nef-specific CD8 and CD4 IFN-gamma SFCs using Nef peptide aa58-66 and aa81-100, respectively. The results are shown in Figure 9A-B. In the experiment 1 (Figure 9A), among the three groups tested, the mice receiving the codon optimized tpanef(LLAA) construct developed the highest CD8 and CD4 cell responses; comparing between tpanef(LLAA) and the nef, the former elicited about 40-fold higher CD8 SFCs and 10-fold higher CD4 SFCs. In contrast to tpanef(LLAA), nef(G2A,LLAA) mutant was poorly immunogenic; mice receiving this mutant had barely detectable CD8 and CD4 SFCs, under conditions tested. Similar response profiles between the three mutants were also observed in the experiment 2 (Figure 9B), except that the overall CD8 response of mice receiving tpanef(LLAA) was approximately 10-fold higher in experiment 2 than that observed in experiment 1. The tPAnef mutant showed comparable responses as that of tpanef(LLAA). The results therefore showed that both codon optimized tpanef and tpanef(LLAA) had significantly enhanced immunogenicity.

*Results (Evaluation of Immunogenicity of nef Mutants in Rhesus Monkeys)* - Monkeys were immunized with 5 mg of indicated codon optimized plasmids at week 0, 4, and 8. Four weeks after each immunization, peripheral blood mononuclear cells were collected and tested for Nef-specific INF-gamma secreting cells as described for the mice studies in this Example section. The results are shown in Table 2. As with the mouse study, tpanef(LLAA) shows significantly enhanced immunogenicity when compared to tPAnef.

TABLE 2

Vaccine	Animal No.	Nef specific INF-gamma secreting cells/million PBMC							
		Week 0		Week 4		Week 8		Week 12	
		Medium	nef	Medium	nef	Medium	nef	Medium	nef
VIJns-TpaNef (LLAA)	1	74	39	30	208	6	148	89	559
	2	1	3	28	45	13	44	13	146
	3	5	5	14	45	11	11	14	35
VIJns-nef	1	0	1	24	33	16	43	6	34
	2	28	9	31	35	13	34	24	80
	3	1	0	16	31	18	38	13	185
Control	1	1	3	16	33	16	16	18	13

- 5 Monkeys were immunized with 5 mg of indicated plasmids at week 0, 4 and 8. Four weeks after each immunization, peripheral blood mononuclear cells were collected and tested for the Nef-specific IFN-gamma secreting cells.

- 10 A codon-optimized nef gene coding for HIV-1 jrf1 isolate Nef polypeptide was synthesized. The resultant synthetic nef gene was well expressed in the *in vitro* transfected cells. Using this synthetic gene as parental molecule, nef mutants involving myristylation site and dileucine motif mutations were constructed. Two forms of myristylation site mutation were made, one involving a single Gly2Ala change and the other by fusing human plasminogen activator(tpa) leader peptide with the N-terminus of Nef polypeptide. The dileucine motif mutation was generated by
- 15 Leu174Ala and Leu175Ala changes. The resultant nef constructs were named as nef, tpanef, tpanef(LLAA) and nef(G2A,LLAA). The addition of tpa leader peptide sequence resulted in significantly increased expression of the nef gene *in vitro*; in contrast, either Gly2Ala mutation or dileucine mutation reduced the nef gene

expression. In an effort to characterize immunogenicity of nef and nef mutants, experiments were carried out to map nef CTL and Th epitopes in mice. A single CTL epitope and a dominant Th epitope, both restricted by H-2b, were identified.

Consequently, C57BL/6 mice were immunized with different nef constructs by DNA  
5 immunization means, and splenocytes from immunized mice were determined for Nef-specific CTL and Th responses using Elisopt assay and the defined T cell epitopes. The results showed that tpanef and tpanef(LLAA) were significantly more immunogenic than nef in terms of eliciting both CTL and Th responses.

Therefore, these aforementioned polynucleotides, when directly introduced  
10 into a vertebrate *in vivo*, including mammals such as primates and humans, should express the respective HIV-1 Nef protein within the animal and in turn induce at least a cytotoxic T lymphocyte (CTL) response within the host to the expressed Nef antigen.

The present invention is not to be limited in scope by the specific  
15 embodiments described herein. Indeed, various modifications of the invention in addition to those described herein will become apparent to those skilled in the art from the foregoing description. Such modifications are intended to fall within the scope of the appended claims.

20

## WHAT IS CLAIMED IS:

1. A pharmaceutically acceptable DNA vaccine, which comprises:  
(a) a DNA expression vector; and,  
5 (b) a DNA molecule containing a codon optimized open reading frame encoding a Nef protein or immunogenic Nef derivative thereof, wherein upon administration of the DNA vaccine to a host the Nef protein or immunogenic Nef derivative is expressed and generates an immune response which provides a substantial level of protection against HIV-1 infection.  
10
2. A DNA vaccine of claim 1 wherein the DNA molecule encodes wild type Nef.
3. A DNA vaccine of claim 2 wherein the DNA molecule contains the  
15 nucleotide sequence as set forth in SEQ ID NO:1.
4. The DNA vaccine of claim 3 which is V1Jns-opt nef (jrfl).
5. A DNA vaccine of claim 2 wherein the DNA molecule expresses a  
20 wild type Nef protein which comprises the amino acid sequence as set forth in SEQ ID NO:2.
6. A DNA vaccine of claim 1 wherein the DNA molecule encodes an immunogenic Nef derivative which contains a nucleotide sequence encoding a leader  
25 peptide.
7. A DNA vaccine of claim 6 wherein the DNA molecule encodes an immunogenic Nef derivative which contains a nucleotide sequence encoding a human tissue plasminogen activator leader peptide.  
30
8. A DNA vaccine of claim 7 wherein the DNA molecule contains the nucleotide sequence as set forth in SEQ ID NO:3.
9. The DNA vaccine of claim 8 which is V1Jns-opt tpanef.

10. A DNA vaccine of claim 7 wherein the DNA molecule expresses an immunogenic Nef derivative which comprises the amino acid sequence as set forth in SEQ ID NO:4.
- 5 11. A DNA vaccine of claim 6 wherein the DNA molecule encodes an immunogenic Nef derivative modified at the dileucine motif of amino acid residue 174 and amino acid residue 175.
- 10 12. A DNA vaccine of claim 11 wherein the DNA molecule encodes an immunogenic Nef derivative which contains a nucleotide sequence encoding a human tissue plasminogen activator leader peptide.
- 15 13. A DNA vaccine of claim 12 wherein the DNA molecule contains the nucleotide sequence as set forth in SEQ ID NO:7.
14. The DNA vaccine of claim 13 which is V1Jns-opt tpanef (LLAA).
- 20 15. A DNA vaccine of claim 11 wherein the DNA molecule expresses an immunogenic Nef derivative which comprises the amino acid sequence as set forth in SEQ ID NO:8.
- 25 16. A DNA vaccine of claim 11 wherein the DNA molecule encodes a Nef protein where the glycine residue of amino acid residue 2 of Nef is modified to encode for an amino acid residue other the glycine.
17. A DNA vaccine of claim 16 wherein the DNA molecule contains the nucleotide sequence as set forth in SEQ ID NO:5.
- 30 18. A DNA vaccine of claim 17 which is V1Jns-opt nef (G2A LLAA).
19. A DNA vaccine of claim 16 wherein the DNA molecule expresses an immunogenic Nef derivative which comprises the amino acid sequence as set forth in SEQ ID NO:6.

20. A DNA vaccine of claim 1 which further comprises an adjuvant.
21. A DNA vaccine of claim 20 wherein the adjuvant is selected from the  
5 group consisting of aluminum phosphate, calcium phosphate and a non-ionic block copolymer.
22. A pharmaceutically acceptable DNA vaccine, which comprises:  
(a) a DNA expression vector; and,  
10 (b) a DNA molecule containing an open reading frame encoding a Nef protein or immunogenic Nef derivative thereof, wherein upon administration of the DNA vaccine to a host the Nef protein or immunogenic Nef derivative is expressed and generates an immune response which provides a substantial level of protection against HIV-1 infection.  
15
23. The DNA vaccine of claim 22 wherein the DNA molecule expresses a wild type Nef protein which comprises the amino acid sequence as set forth in the group consisting of SEQ ID NO:2, SEQ ID NO:4, SEQ ID NO:6 and SEQ ID NO:8.
- 20 24. A DNA vaccine of claim 22 which further comprises an adjuvant.
25. A DNA vaccine of claim 23 wherein the adjuvant is selected from the group consisting of aluminum phosphate, calcium phosphate and a non-ionic block copolymer.  
25
26. A method for inducing a cell mediated immune (CTL) response against infection or disease caused by virulent strains of HIV which comprises administering into the tissue of a vertebrate host a pharmaceutically acceptable DNA vaccine composition which comprises a DNA expression vector and a DNA molecule  
30 containing a codon optimized open reading frame encoding a Nef protein or immunogenic Nef derivative thereof, wherein upon administration of the DNA vaccine to the vertebrate host the Nef protein or immunogenic Nef derivative is expressed and generates the cell-mediated immune (CTL) response.

27. The method of claim 26 wherein the vertebrate host is a human.

28. The method of claim 26 wherein the DNA vaccine is selected from the group consisting of V1Jns-opt nef (jrf1), V1Jns-opt tpanef, V1Jns-opt tpanef (LLAA),  
5 and V1Jns-opt nef (G2A LLAA).

29. A substantially purified protein which comprises an amino acid sequence selected from the group consisting of SEQ ID NO:4, SEQ ID NO:6, and SEQ ID NO:8.  
10



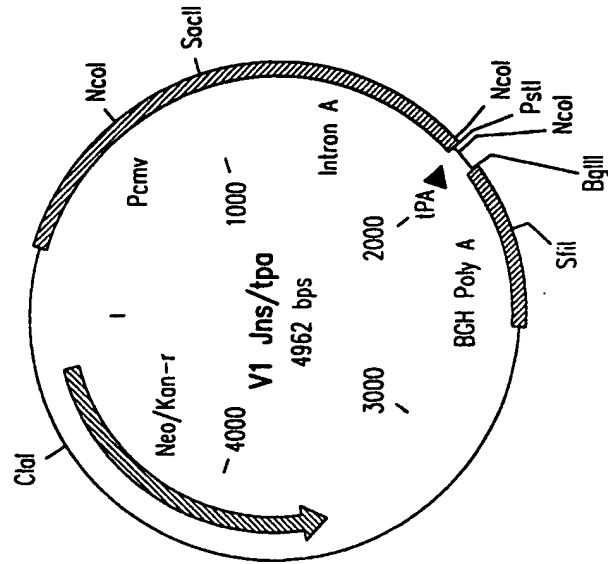


FIG.1B

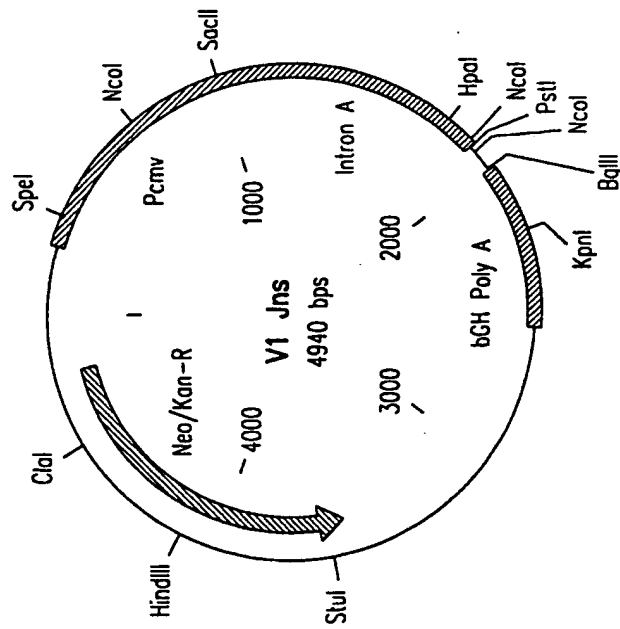


FIG.1A

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WT	-	ATG GGT GGC AAG TGG TCA AAA CGT AGT GTG CCT GGA TGG TCT	-42
OPT	-	ATG GGC GGC AAG TGG TCC AAG AGG TCC GTG CCC GGC TGG TCC	
		M G G K W S K R S V P G W S	-14
WT	-	ACT GTA AGG GAA AGA ATG AGA CGA GCT GAG CCA GCA GCA GAT	-84
OPT	-	ACC GTG AGG GAG AGG ATG AGG AGG GCC GAG CCC GCC GCC GAC	
		T V R E R M R R A E P A A D	-28
WT	-	AGG GTG AGA CGA ACT GAG CCA GCA GCA GTA GGG GTG GGA GCA	-126
OPT	-	AGG GTG AGG AGG ACC GAG CCC GCC GCC GTG GGC GTG GGC GCC	
		R V R R T E P A A V G V G A	-42
WT	-	GTA TCT CGA GAC CTG GAA AAA CAT GGA GCA ATC ACA AGT AGC	-168
OPT	-	GTG TCC AGG GAC CTG GAG AAG CAC GGC GCC ATC ACC TCC TCC	
		V S R D L E K H G A I T S S	-56
WT	-	AAT ACA GCA GCT ACC AAT GCT GAT TGT GCC TGG CTA GAA GCA	-210
OPT	-	AAC ACC GCC GCC ACC AAC GCC GAC TGC GCC TGG CTG GAG GCC	
		N T A A T N A D C A W L E A	-70
WT	-	CAA GAG GAT GAG GAA GTG GGT TTT CCA GTC AGA CCT CAG GTA	-252
OPT	-	CAG GAG GAC GAG GAG GTG GGC TTC CCC GTG AGG CCC CAG GTG	
		Q E D E E V G F P V R P Q V	-84
WT	-	CCT TTA AGA CCA ATG ACT TAC AAG GGA GCT GTA GAT CTT AGC	-294
OPT	-	CCC CTG AGG CCC ATG ACC TAC AAG GGC GCC GTG GAC CTG TCC	
		P L R P M T Y K G A V D L S	-98
WT	-	CAC TTT TTA AAA GAA AAG GGG GGA CTG GAA GGG CTA ATT CAC	-336
OPT	-	CAC TTC CTG AAG GAG AAG GGC GGC CTG GAG GGC CTG ATC CAC	
		H F L K E K G G L E G L I H	-112
WT	-	TCA CAG AAA AGA CAA GAT ATC CTT GAT CTG TGG GTC TAC CAC	-378
OPT	-	TCC CAG AAG AGG CAG GAC ATC CTG GAC CTG TGG GTG TAC CAC	
		S Q K R Q D I L D L W V Y H	-126
WT	-	ACA CAA GGC TAC TTC CCT GAT TGG CAG AAC TAC ACA CCA GGG	-420
OPT	-	ACC CAG GGC TAC TTC CCC GAC TGG CAG AAC TAC ACC CCC GGC	
		T Q G Y F P D W Q N Y T P G	-140

FIG.2A

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WT	- CCA GGA ATC AGA TTT CCA TTG ACC TTT GGA TGG TGC TTC AAG	-462
OPT	- CCC GGC ATC AGG TTC CCC CTG ACC TTC GGC TGG TGC TTC AAG	
	P G I R F P L T F G W C F K	-154
WT	- CTA GTA CCA GTT GAG CCA GAA AAG GTA GAA GAG GCC AAT GAA	-504
OPT	- CTG GTG CCC GTG GAG CCC GAG AAG GTG GAG GAG GCC AAC GAG	
	L V P V E P E K V E E A N E	-168
WT	- GGA GAG AAC AAC TGC TTG TTA CAC CCT ATG AGC CAG CAT GGG	-546
OPT	- GGC GAG AAC AAC TGC CTG CTG CAC CCC ATG TCC CAG CAC GGC	
	G E N N C L L H P M S Q H G	-182
WT	- ATA GAG GAC CCG GAG AAG GAA GTG TTA GAG TGG AGG TTT GAC	-588
OPT	- ATC GAG GAC CCC GAG AAG GAG GTG CTG GAG TGG AGG TTC GAC	
	I E D P E K E V L E W R F D	-196
WT	- AGC AAG CTA GCA TTT CAT CAC GTG GCC CGA GAG CTG CAT CCG	-630
OPT	- TCC AAG CTG GCC TTC CAC CAC GTG GCC AGG GAG CTG CAC CCC	
	S K L A F H H V A R E L H P	-210
WT	- GAG TAC TAC AAG GAC TGC TGA (SEQ ID NO:30)	-651
OPT	- GAG TAC TAC AAG GAC TGC TAA (contained within SEQ ID NO:1)	
	E Y Y K D C (SEQ ID NO:2)	-216

FIG.2B

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VIJns/nef *PstI* *BglIII*  
 CATGGGTCCTTTTCIGCAGTCACCGTCCTTGAATCTGCCACC ATG GGC GGC AAG TGG TCC AAG AGG TCC GTG CCC  
 M G G K W S K R S V P  
 . . . . . CAC CCC GAG TAC TAC AAG GAC TGC TAA *SrfI* *BglIII*  
 H P E Y Y K D C \* AGCCCGGGCAGATCTGCTGTGCTTCTAGTTGCCAGC (SEQ ID NO:27)  
 (contained within SEQ ID NO:2)

## FIG.3A

VIJns/nef(G2A,LLAA)  
*PstI* *BglIII*  
 CATGGGTCCTTTTCIGCAGTCACCGTCCTTGAATCTGCCACC ATG GCC GGC AAG TGG TCC AAG AGG TCC GTG CCC  
 M A G K W S K R S V P  
 . . . . . CAC CCC GAG TAC TAC AAG GAC TGC TAA *SrfI* *BglIII*  
 H P E Y Y K D C \* AGCCCGGGCAGATCTGCTGTGCTTCTAGTTGCCAGC (SEQ ID NO:28)  
 (contained within SEQ ID NO:6)

## FIG.3B

VIJns/tpanef & VIJns/tpanef(LLAA)  
*PstI* *BglIII*  
 CATGGGTCCTTTTCIGCAGTCACCGTCCTTATCTAGATCACC ATG GAT GCA ATG AAG AGA GGG CTC TGC TGT GTG  
 M D A M K R G L C C V  
 CTG CTG CTG TGT GGA GCA GTC TTC GTT TCG CCC AGC GAG ATC TCC TCC AAG AGG TCC GTG CCC  
 L L L C G A V F V S P S E I S S K R S V P  
 . . . . . CAC CCC GAG TAC TAC AAG GAC TGC TAA *SrfI* *BglIII*  
 H P E Y Y K D C \* AGCCCGGGCAGATCTGCTGTGCTTCTAGTTGCCAGC (SEQ ID NO:29)  
 (contained within SEQ ID NO:8)

## FIG.3C

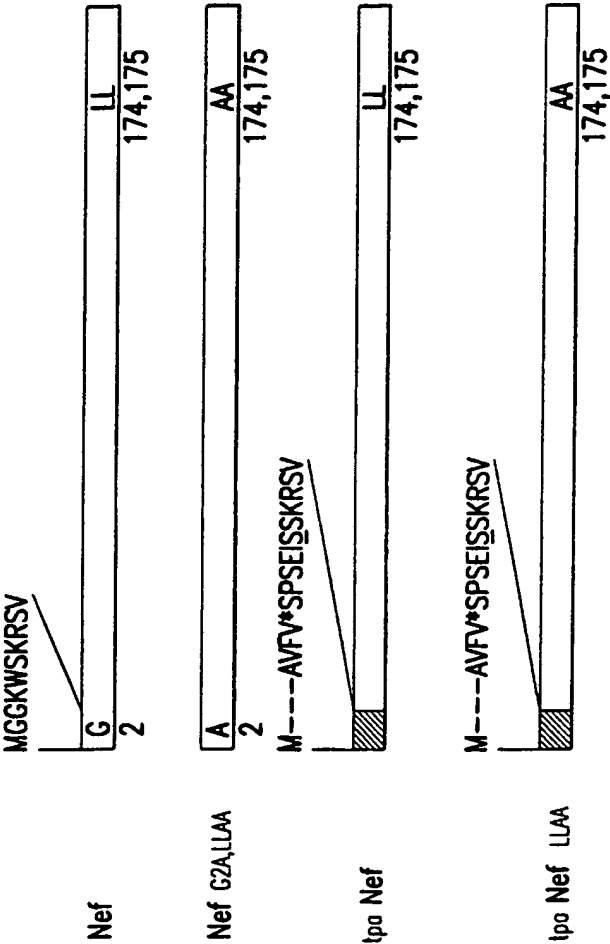


FIG.4

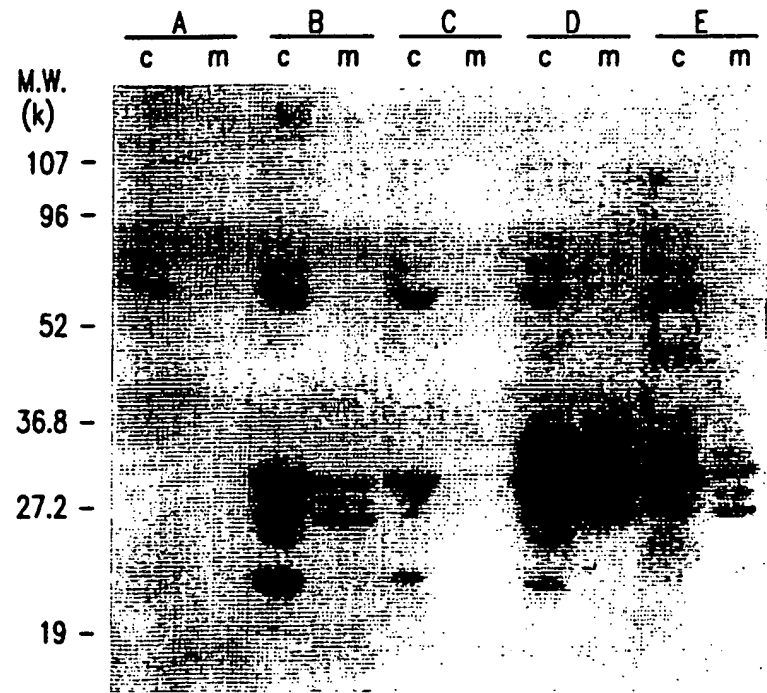


FIG.5

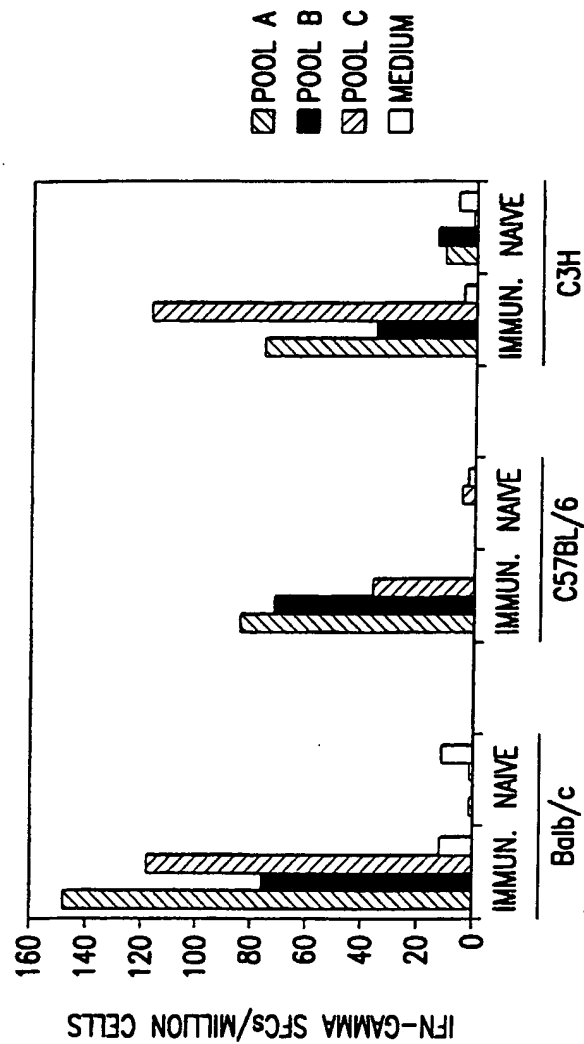
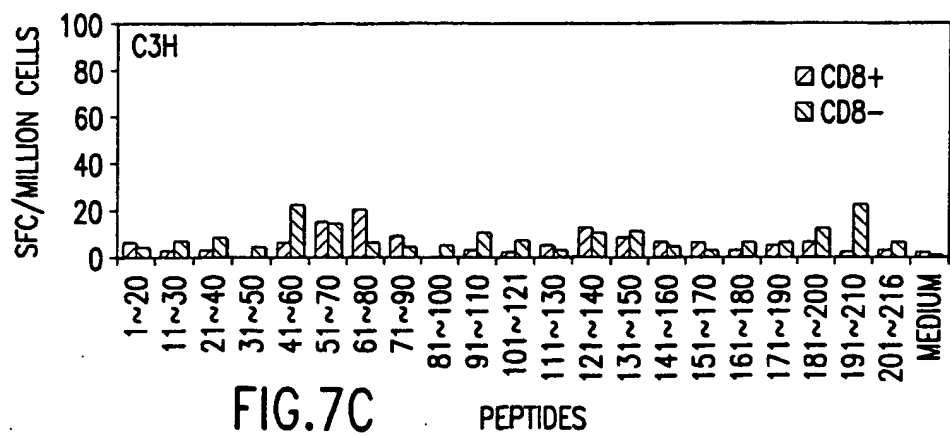
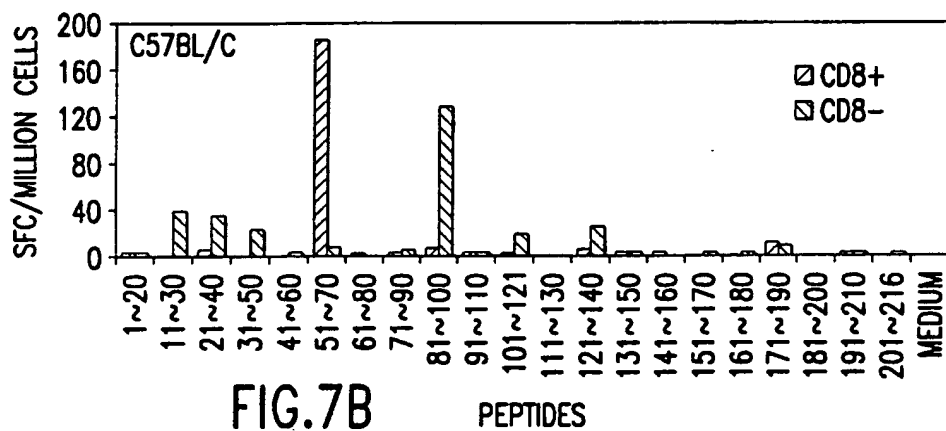
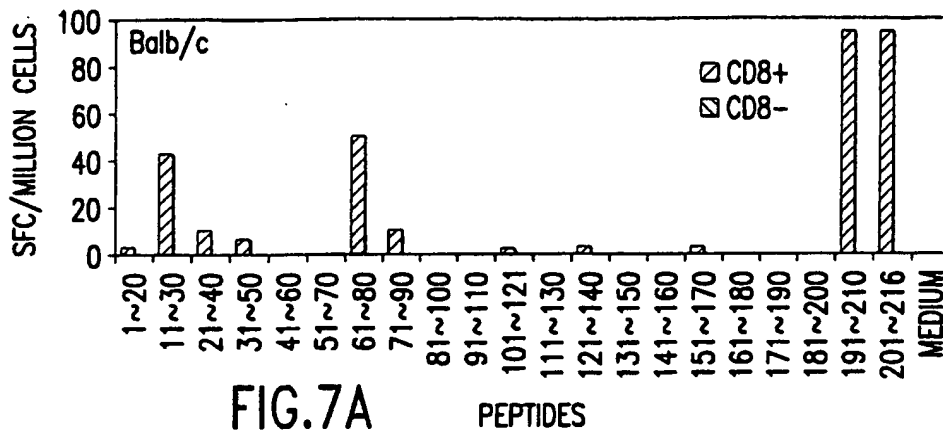


FIG.6

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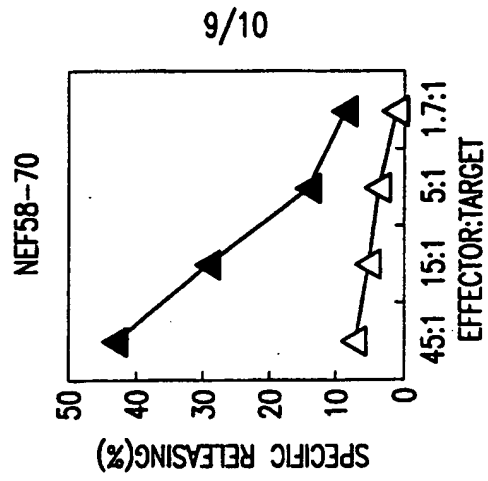


FIG.8C

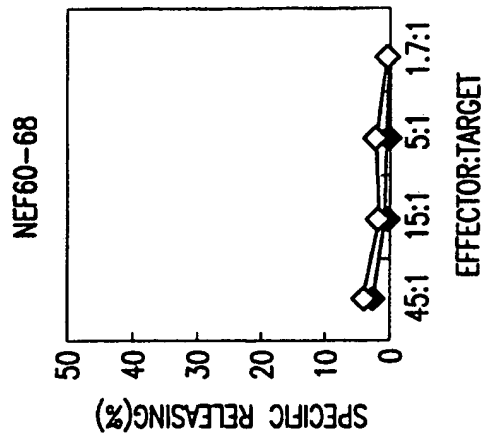


FIG.8B

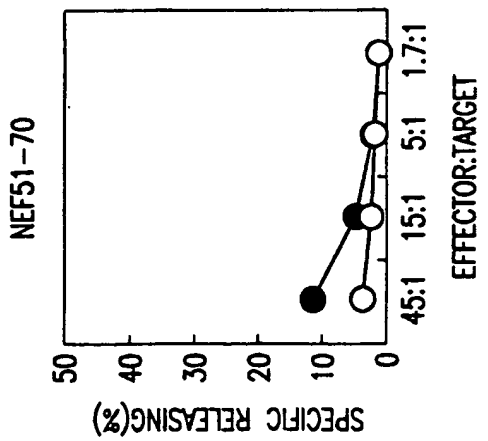
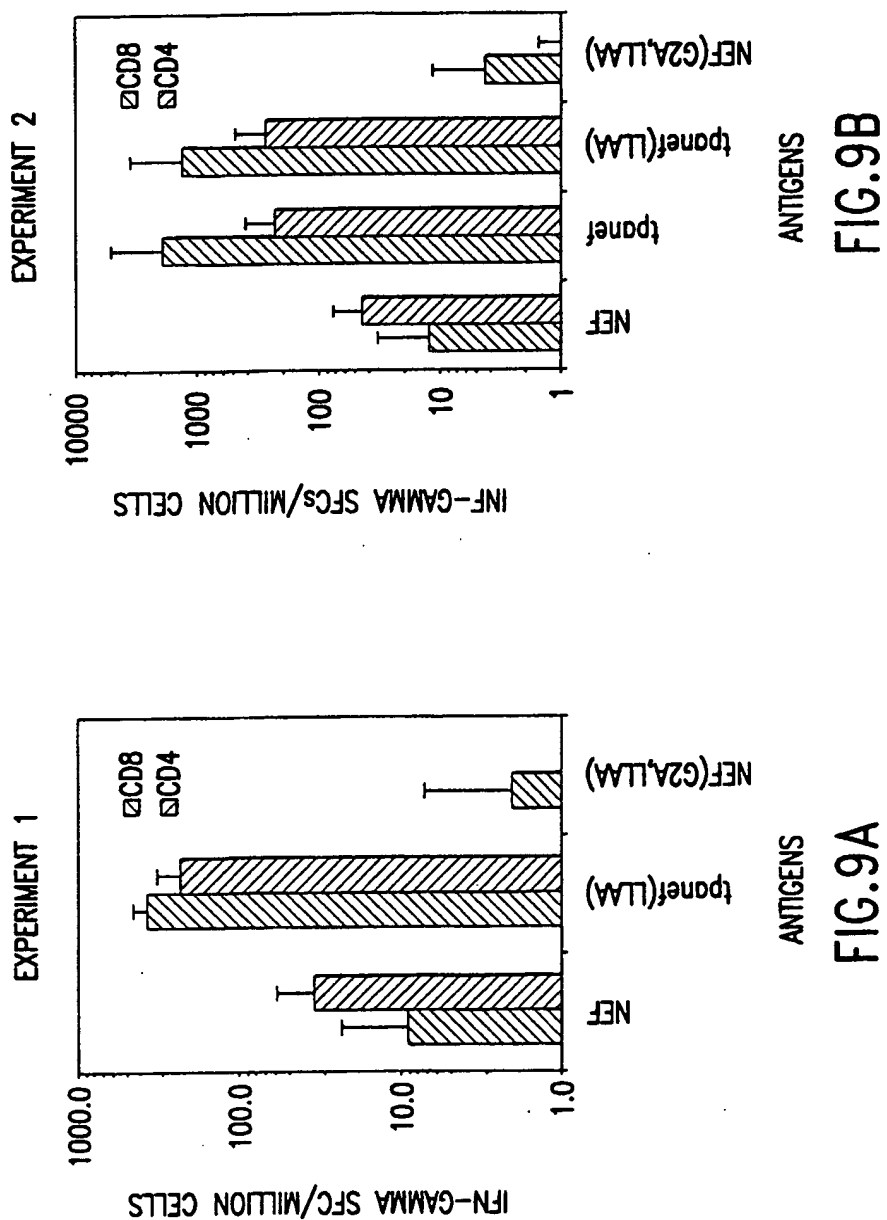


FIG.8A

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## SEQUENCE LISTING

&lt;110&gt; APPLICANT: Merck &amp; Co., Inc.

<120> TITLE: POLYNUCLEOTIDE VACCINES EXPRESSING CODON  
OPTIMIZED HIV-1 NEF AND MODIFIED HIV-1 NEF

&lt;130&gt; DOCKET/FILE REFERENCE: 20602Y

&lt;160&gt; NUMBER OF SEQUENCES: 30

&lt;170&gt; SOFTWARE: FastSEQ for Windows Version 4.0

&lt;210&gt; SEQ ID NO:1

&lt;211&gt; LENGTH: 671

&lt;212&gt; TYPE: DNA

&lt;213&gt; ORGANISM: Human Immunodeficiency Virus - 1

&lt;220&gt; FEATURE:

&lt;221&gt; NAME/KEY: CDS

&lt;222&gt; LOCATION: (12)...(662)

&lt;400&gt; SEQ ID NO:1

gatctgccac c atg ggc ggc aag tgg tcc aag agg tcc gtg ccc ggc tgg	50
Met Gly Gly Lys Trp Ser Lys Arg Ser Val Pro Gly Trp	
1 5 10	
tcc acc gtg agg gag agg atg agg agg gcc gag ccc gcc gcc gac agg	98
Ser Thr Val Arg Glu Arg Met Arg Arg Ala Glu Pro Ala Ala Asp Arg	
15 20 25	
gtg agg agg acc gag ccc gcc gcc gtg ggc gtg ggc gcc gtg tcc agg	146
Val Arg Arg Thr Glu Pro Ala Ala Val Gly Val Gly Ala Val Ser Arg	
30 35 40 45	
gac ctg gag aag cac ggc gcc atc acc tcc tcc aac acc gcc gcc acc	194
Asp Leu Glu Lys His Gly Ala Ile Thr Ser Ser Asn Thr Ala Ala Thr	
50 55 60	
aac gcc gac tgc gcc tgg ctg gag gcc cag gag gac gag gag gtg ggc	242
Asn Ala Asp Cys Ala Trp Leu Glu Ala Gln Glu Asp Glu Glu Val Gly	
65 70 75	
ttc ccc gtg agg ccc cag gtg ccc ctg agg ccc atg acc tac aag ggc	290
Phe Pro Val Arg Pro Gln Val Pro Leu Arg Pro Met Thr Tyr Lys Gly	
80 85 90	
gcc gtg gac ctg tcc cac ttc ctg aag gag aag ggc ggc ctg gag ggc	338
Ala Val Asp Leu Ser His Phe Leu Lys Glu Lys Gly Gly Leu Glu Gly	
95 100 105	
ctg atc cac tcc cag aag agg cag gac atc ctg gac ctg tgg gtg tac	386
Leu Ile His Ser Gln Lys Arg Gln Asp Ile Leu Asp Leu Trp Val Tyr	
110 115 120 125	
cac acc cag ggc tac ttc ccc gac tgg cag aac tac acc ccc ggc ccc	434
His Thr Gln Gly Tyr Phe Pro Asp Trp Gln Asn Tyr Thr Pro Gly Pro	

	130		135		140	
ggc atc agg ttc ccc ctg acc ttc ggc tgg tgc ttc aag ctg gtg ccc						482
Gly Ile Arg Phe Pro Leu Thr Phe Gly Trp Cys Phe Lys Leu Val Pro						
	145		150		155	
gtg gag ccc gag aag gtg gag gag gcc aac gag ggc gag aac aac tgc						530
Val Glu Pro Glu Lys Val Glu Glu Ala Asn Glu Gly Glu Asn Asn Cys						
	160		165		170	
ctg ctg cac ccc atg tcc cag cac ggc atc gag gac ccc gag aag gag						578
Leu Leu His Pro Met Ser Gln His Gly Ile Glu Asp Pro Glu Lys Glu						
	175		180		185	
gtg ctg gag tgg agg ttc gac tcc aag ctg gcc ttc cac cac gtg gcc						626
Val Leu Glu Trp Arg Phe Asp Ser Lys Leu Ala Phe His His Val Ala						
	190		195		200	205
agg gag ctg cac ccc gag tac tac aag gac tgc taa agcccgggc						671
Arg Glu Leu His Pro Glu Tyr Tyr Lys Asp Cys *						
	210		215			

&lt;210&gt; SEQ ID NO:2

&lt;211&gt; LENGTH: 216

&lt;212&gt; TYPE: PRT

&lt;213&gt; ORGANISM:Human Immunodeficiency Virus - 1

&lt;400&gt; SEQ ID NO:2

Met Gly Gly Lys Trp Ser Lys Arg Ser Val Pro Gly Trp Ser Thr Val															
1		5					10						15		
Arg Glu Arg Met Arg Arg Ala Glu Pro Ala Ala Asp Arg Val Arg Arg							25					30			
	20														
Thr Glu Pro Ala Ala Val Gly Val Gly Ala Val Ser Arg Asp Leu Glu							40				45				
	35														
Lys His Gly Ala Ile Thr Ser Ser Asn Thr Ala Ala Thr Asn Ala Asp							55			60					
	50														
Cys Ala Trp Leu Glu Ala Gln Glu Asp Glu Glu Val Gly Phe Pro Val							70		75				80		
	65														
Arg Pro Gln Val Pro Leu Arg Pro Met Thr Tyr Lys Gly Ala Val Asp							85		90				95		
Leu Ser His Phe Leu Lys Glu Lys Gly Gly Leu Glu Gly Leu Ile His							100		105				110		
Ser Gln Lys Arg Gln Asp Ile Leu Asp Leu Trp Val Tyr His Thr Gln							115		120				125		
Gly Tyr Phe Pro Asp Trp Gln Asn Tyr Thr Pro Gly Pro Gly Ile Arg							130		135				140		
Phe Pro Leu Thr Phe Gly Trp Cys Phe Lys Leu Val Pro Val Glu Pro							145		150			155			160
Glu Lys Val Glu Glu Ala Asn Glu Gly Glu Asn Asn Cys Leu Leu His							165		170						175
Pro Met Ser Gln His Gly Ile Glu Asp Pro Glu Lys Glu Val Leu Glu							180		185				190		
Trp Arg Phe Asp Ser Lys Leu Ala Phe His His Val Ala Arg Glu Leu							195		200				205		
His Pro Glu Tyr Tyr Lys Asp Cys							210		215						

&lt;210&gt; SEQ ID NO:3

&lt;211&gt; LENGTH: 719

&lt;212&gt; TYPE: DNA

&lt;213&gt; ORGANISM: Human Immunodeficiency Virus - 1

&lt;220&gt; FEATURE:

&lt;221&gt; NAME/KEY: CDS

&lt;222&gt; LOCATION: (2)...(715)

&lt;400&gt; SEQ ID NO:3

```

c atg gat gca atg aag aga ggg ctc tgc tgt gtg ctg ctg ctg tgt gga      49
Met Asp Ala Met Lys Arg Gly Leu Cys Cys Val Leu Leu Leu Cys Gly
   1             5             10             15

gca gtc ttc gtt tcg ccc agc gag atc tcc tcc aag agg tcc gtg ccc      97
Ala Val Phe Val Ser Pro Ser Glu Ile Ser Ser Lys Arg Ser Val Pro
   20             25             30

ggc tgg tcc acc gtg agg gag agg atg agg agg gcc gag ccc gcc gcc     145
Gly Trp Ser Thr Val Arg Glu Arg Met Arg Arg Ala Glu Pro Ala Ala
   35             40             45

gac agg gtg agg agg acc gag ccc gcc gcc gtg ggc gtg ggc gcc gtg     193
Asp Arg Val Arg Arg Thr Glu Pro Ala Ala Val Gly Val Gly Ala Val
   50             55             60

tcc agg gac ctg gag aag cac ggc gcc atc acc tcc tcc aac acc gcc     241
Ser Arg Asp Leu Glu Lys His Gly Ala Ile Thr Ser Ser Asn Thr Ala
   65             70             75             80

gcc acc aac gcc gac tgc gcc tgg ctg gag gcc cag gag gac gag gag     289
Ala Thr Asn Ala Asp Cys Ala Trp Leu Glu Ala Gln Glu Asp Glu Glu
   85             90             95

gtg ggc ttc ccc gtg agg ccc cag gtg ccc ctg agg ccc atg acc tac     337
Val Gly Phe Pro Val Arg Pro Gln Val Pro Leu Arg Pro Met Thr Tyr
  100             105             110

aag ggc gcc gtg gac ctg tcc cac ttc ctg aag gag aag ggc ggc ctg     385
Lys Gly Ala Val Asp Leu Ser His Phe Leu Lys Glu Lys Gly Gly Leu
  115             120             125

gag ggc ctg atc cac tcc cag aag agg cag gac atc ctg gac ctg tgg     433
Glu Gly Leu Ile His Ser Gln Lys Arg Gln Asp Ile Leu Asp Leu Trp
  130             135             140

gtg tac cac acc cag ggc tac ttc ccc gac tgg cag aac tac acc ccc     481
Val Tyr His Thr Gln Gly Tyr Phe Pro Asp Trp Gln Asn Tyr Thr Pro
  145             150             155             160

ggc ccc ggc atc agg ttc ccc ctg acc ttc ggc tgg tgc ttc aag ctg     529
Gly Pro Gly Ile Arg Phe Pro Leu Thr Phe Gly Trp Cys Phe Lys Leu
  165             170             175

gtg ccc gtg gag ccc gag aag gtg gag gag gcc aac gag ggc gag aac     577
Val Pro Val Glu Pro Glu Lys Val Glu Glu Ala Asn Glu Gly Glu Asn
  180             185             190

aac tgc ctg ctg cac ccc atg tcc cag cac ggc atc gag gac ccc gag     625
Asn Cys Leu Leu His Pro Met Ser Gln His Gly Ile Glu Asp Pro Glu
  195             200             205

aag gag gtg ctg gag tgg agg ttc gac tcc aag ctg gcc ttc cac cac     673

```

Lys Glu Val Leu Glu Trp Arg Phe Asp Ser Lys Leu Ala Phe His His  
 210 215 220

gtg gcc agg gag ctg cac ccc gag tac tac aag gac tgc taa 715  
 Val Ala Arg Glu Leu His Pro Glu Tyr Tyr Lys Asp Cys \*  
 225 230 235

agcc 719

<210> SEQ ID NO:4  
 <211> LENGTH: 237  
 <212> TYPE: PRT  
 <213> ORGANISM:Human Immunodeficiency Virus - 1

<400> SEQ ID NO:4  
 Met Asp Ala Met Lys Arg Gly Leu Cys Cys Val Leu Leu Leu Cys Gly  
 1 5 10 15  
 Ala Val Phe Val Ser Pro Ser Glu Ile Ser Ser Lys Arg Ser Val Pro  
 20 25 30  
 Gly Trp Ser Thr Val Arg Glu Arg Met Arg Arg Ala Glu Pro Ala Ala  
 35 40 45  
 Asp Arg Val Arg Arg Thr Glu Pro Ala Ala Val Gly Val Gly Ala Val  
 50 55 60  
 Ser Arg Asp Leu Glu Lys His Gly Ala Ile Thr Ser Ser Asn Thr Ala  
 65 70 75 80  
 Ala Thr Asn Ala Asp Cys Ala Trp Leu Glu Ala Gln Glu Asp Glu Glu  
 85 90 95  
 Val Gly Phe Pro Val Arg Pro Gln Val Pro Leu Arg Pro Met Thr Tyr  
 100 105 110  
 Lys Gly Ala Val Asp Leu Ser His Phe Leu Lys Glu Lys Gly Gly Leu  
 115 120 125  
 Glu Gly Leu Ile His Ser Gln Lys Arg Gln Asp Ile Leu Asp Leu Trp  
 130 135 140  
 Val Tyr His Thr Gln Gly Tyr Phe Pro Asp Trp Gln Asn Tyr Thr Pro  
 145 150 155 160  
 Gly Pro Gly Ile Arg Phe Pro Leu Thr Phe Gly Trp Cys Phe Lys Leu  
 165 170 175  
 Val Pro Val Glu Pro Glu Lys Val Glu Glu Ala Asn Glu Gly Glu Asn  
 180 185 190  
 Asn Cys Leu Leu His Pro Met Ser Gln His Gly Ile Glu Asp Pro Glu  
 195 200 205  
 Lys Glu Val Leu Glu Trp Arg Phe Asp Ser Lys Leu Ala Phe His His  
 210 215 220  
 Val Ala Arg Glu Leu His Pro Glu Tyr Tyr Lys Asp Cys  
 225 230 235

<210> SEQ ID NO:5  
 <211> LENGTH: 671  
 <212> TYPE: DNA  
 <213> ORGANISM:Human Immunodeficiency Virus - 1

<220> FEATURE:  
 <221> NAME/KEY: CDS  
 <222> LOCATION: (12)...(662)

<400> SEQ ID NO:5  
 gatctgccac c atg gcc ggc aag tgg tcc aag agg tcc gtg ccc ggc tgg 50  
 Met Ala Gly Lys Trp Ser Lys Arg Ser Val Pro Gly Trp  
 1 5 10  
 tcc acc gtg agg gag agg atg agg agg gcc gag ccc gcc gcc gac agg 98

```

Ser Thr Val Arg Glu Arg Met Arg Arg Ala Glu Pro Ala Ala Asp Arg
  15                20                25

gtg agg agg acc gag ccc gcc gcc gtg gcc gtg gcc gcc gtg tcc agg    146
Val Arg Arg Thr Glu Pro Ala Ala Val Gly Val Gly Ala Val Ser Arg
  30                35                40                45

gac ctg gag aag cac gcc gcc atc acc tcc tcc aac acc gcc gcc acc    194
Asp Leu Glu Lys His Gly Ala Ile Thr Ser Ser Asn Thr Ala Ala Thr
      50                55                60

aac gcc gac tgc gcc tgg ctg gag gcc cag gag gac gag gag gtg gcc    242
Asn Ala Asp Cys Ala Trp Leu Glu Ala Gln Glu Asp Glu Glu Val Gly
      65                70                75

ttc ccc gtg agg ccc cag gtg ccc ctg agg ccc atg acc tac aag gcc    290
Phe Pro Val Arg Pro Gln Val Pro Leu Arg Pro Met Thr Tyr Lys Gly
      80                85                90

gcc gtg gac ctg tcc cac ttc ctg aag gag aag gcc gcc ctg gag gcc    338
Ala Val Asp Leu Ser His Phe Leu Lys Glu Lys Gly Gly Leu Glu Gly
      95                100                105

ctg atc cac tcc cag aag agg cag gac atc ctg gac ctg tgg gtg tac    386
Leu Ile His Ser Gln Lys Arg Gln Asp Ile Leu Asp Leu Trp Val Tyr
     110                115                120                125

cac acc cag gcc tac ttc ccc gac tgg cag aac tac acc ccc gcc ccc    434
His Thr Gln Gly Tyr Phe Pro Asp Trp Gln Asn Tyr Thr Pro Gly Pro
      130                135                140

gcc atc agg ttc ccc ctg acc ttc gcc tgg tgc ttc aag ctg gtg ccc    482
Gly Ile Arg Phe Pro Leu Thr Phe Gly Trp Cys Phe Lys Leu Val Pro
      145                150                155

gtg gag ccc gag aag gtg gag gag gcc aac gag gcc gag aac aac tgc    530
Val Glu Pro Glu Lys Val Glu Glu Ala Asn Glu Gly Glu Asn Asn Cys
      160                165                170

gcc gcc cac ccc atg tcc cag cac gcc atc gag gac ccc gag aag gag    578
Ala Ala His Pro Met Ser Gln His Gly Ile Glu Asp Pro Glu Lys Glu
      175                180                185

gtg ctg gag tgg agg ttc gac tcc aag ctg gcc ttc cac cac gtg gcc    626
Val Leu Glu Trp Arg Phe Asp Ser Lys Leu Ala Phe His His Val Ala
     190                195                200                205

agg gag ctg cac ccc gag tac tac aag gac tgc taa agcccgggc        671
Arg Glu Leu His Pro Glu Tyr Tyr Lys Asp Cys *
      210                215

```

&lt;210&gt; SEQ ID NO:6

&lt;211&gt; LENGTH: 217

&lt;212&gt; TYPE: PRT

&lt;213&gt; ORGANISM: Human Immunodeficiency Virus - 1

&lt;400&gt; SEQ ID NO:6

Met Ala Gly Lys Trp Ser Lys Arg Ser Val Pro Gly Trp Ser Thr Val

```

      1           5           10           15
Arg Glu Arg Met Arg Arg Ala Glu Pro Ala Ala Asp Arg Val Arg Arg
      20           25           30
Thr Glu Pro Ala Ala Val Gly Val Gly Ala Val Ser Arg Asp Leu Glu
      35           40           45
Lys His Gly Ala Ile Thr Ser Ser Asn Thr Ala Ala Thr Asn Ala Asp
      50           55           60
Cys Ala Trp Leu Glu Ala Gln Glu Asp Glu Glu Val Gly Phe Pro Val
      65           70           75           80
Arg Pro Gln Val Pro Leu Arg Pro Met Thr Tyr Lys Gly Ala Val Asp
      85           90           95
Leu Ser His Phe Leu Lys Glu Lys Gly Gly Leu Glu Gly Leu Ile His
      100          105          110
Ser Gln Lys Arg Gln Asp Ile Leu Asp Leu Trp Val Tyr His Thr Gln
      115          120          125
Gly Tyr Phe Pro Asp Trp Gln Asn Tyr Thr Pro Gly Pro Gly Ile Arg
      130          135          140
Phe Pro Leu Thr Phe Gly Trp Cys Phe Lys Leu Val Pro Val Glu Pro
      145          150          155          160
Glu Lys Val Glu Glu Ala Asn Glu Gly Glu Asn Asn Cys Ala Ala His
      165          170          175
Pro Met Ser Gln His Gly Ile Glu Asp Pro Glu Lys Glu Val Leu Glu
      180          185          190
Trp Arg Phe Asp Ser Lys Leu Ala Phe His His Val Ala Arg Glu Leu
      195          200          205
His Pro Glu Tyr Tyr Lys Asp Cys Ser
      210          215

```

&lt;210&gt; SEQ ID NO:7

&lt;211&gt; LENGTH: 720

&lt;212&gt; TYPE: DNA

&lt;213&gt; ORGANISM: Human Immunodeficiency Virus - 1

&lt;220&gt; FEATURE:

&lt;221&gt; NAME/KEY: CDS

&lt;222&gt; LOCATION: (2)...(715)

&lt;400&gt; SEQ ID NO:7

```

c atg gat gca atg aag aga ggg ctc tgc tgt gtg ctg ctg ctg tgt gga      49
  Met Asp Ala Met Lys Arg Gly Leu Cys Cys Val Leu Leu Leu Cys Gly
    1           5           10           15

gca gtc ttc gtt tgc ccc agc gag atc tcc tcc aag agg tcc gtg ccc      97
Ala Val Phe Val Ser Pro Ser Glu Ile Ser Ser Lys Arg Ser Val Pro
      20           25           30

ggc tgg tcc acc gtg agg gag agg atg agg agg gcc gag ccc gcc gcc      145
Gly Trp Ser Thr Val Arg Glu Arg Met Arg Arg Ala Glu Pro Ala Ala
      35           40           45

gac agg gtg agg agg acc gag ccc gcc gcc gtg ggc gtg ggc gcc gtg      193
Asp Arg Val Arg Arg Thr Glu Pro Ala Ala Val Gly Val Gly Ala Val
      50           55           60

tcc agg gac ctg gag aag cac ggc gcc atc acc tcc tcc aac acc gcc      241
Ser Arg Asp Leu Glu Lys His Gly Ala Ile Thr Ser Ser Asn Thr Ala
      65           70           75           80

gcc acc aac gcc gac tgc gcc tgg ctg gag gcc cag gag gac gag gag      289
Ala Thr Asn Ala Asp Cys Ala Trp Leu Glu Ala Gln Glu Asp Glu Glu

```



	85	90	95	
gtg ggc ttc ccc gtg agg ccc cag gtg ccc ctg agg ccc atg acc tac				337
Val Gly Phe Pro Val Arg Pro Gln Val Pro Leu Arg Pro Met Thr Tyr				
	100	105	110	
aag ggc gcc gtg gac ctg tcc cac ttc ctg aag gag aag ggc ggc ctg				385
Lys Gly Ala Val Asp Leu Ser His Phe Leu Lys Glu Lys Gly Gly Leu				
	115	120	125	
gag ggc ctg atc cac tcc cag aag agg cag gac atc ctg gac ctg tgg				433
Glu Gly Leu Ile His Ser Gln Lys Arg Gln Asp Ile Leu Asp Leu Trp				
	130	135	140	
gtg tac cac acc cag ggc tac ttc ccc gac tgg cag aac tac acc ccc				481
Val Tyr His Thr Gln Gly Tyr Phe Pro Asp Trp Gln Asn Tyr Thr Pro				
	145	150	155	160
ggc ccc ggc atc agg ttc ccc ctg acc ttc ggc tgg tgc ttc aag ctg				529
Gly Pro Gly Ile Arg Phe Pro Leu Thr Phe Gly Trp Cys Phe Lys Leu				
	165	170	175	
gtg ccc gtg gag ccc gag aag gtg gag gag gcc aac gag ggc gag aac				577
Val Pro Val Glu Pro Glu Lys Val Glu Glu Ala Asn Glu Gly Glu Asn				
	180	185	190	
aac tgc gcc gcc cac ccc atg tcc cag cac ggc atc gag gac ccc gag				625
Asn Cys Ala Ala His Pro Met Ser Gln His Gly Ile Glu Asp Pro Glu				
	195	200	205	
aag gag gtg ctg gag tgg agg ttc gac tcc aag ctg gcc ttc cac cac				673
Lys Glu Val Leu Glu Trp Arg Phe Asp Ser Lys Leu Ala Phe His His				
	210	215	220	
gtg gcc agg gag ctg cac ccc gag tac tac aag gac tgc taa				715
Val Ala Arg Glu Leu His Pro Glu Tyr Tyr Lys Asp Cys *				
	225	230	235	
agccc				720

&lt;210&gt; SEQ ID NO:8

&lt;211&gt; LENGTH: 237

&lt;212&gt; TYPE: PRT

&lt;213&gt; ORGANISM:Human Immunodeficiency Virus - 1

&lt;400&gt; SEQ ID NO:8

Met Asp Ala Met Lys Arg Gly Leu Cys Cys Val Leu Leu Leu Cys Gly				
1	5	10	15	
Ala Val Phe Val Ser Pro Ser Glu Ile Ser Ser Lys Arg Ser Val Pro				
	20	25	30	
Gly Trp Ser Thr Val Arg Glu Arg Met Arg Arg Ala Glu Pro Ala Ala				
	35	40	45	
Asp Arg Val Arg Arg Thr Glu Pro Ala Ala Val Gly Val Gly Ala Val				
	50	55	60	
Ser Arg Asp Leu Glu Lys His Gly Ala Ile Thr Ser Ser Asn Thr Ala				
	65	70	75	80
Ala Thr Asn Ala Asp Cys Ala Trp Leu Glu Ala Gln Glu Asp Glu Glu				
	85	90	95	
Val Gly Phe Pro Val Arg Pro Gln Val Pro Leu Arg Pro Met Thr Tyr				
	100	105	110	

Lys Gly Ala Val Asp Leu Ser His Phe Leu Lys Glu Lys Gly Gly Leu  
 115 120 125  
 Glu Gly Leu Ile His Ser Gln Lys Arg Gln Asp Ile Leu Asp Leu Trp  
 130 135 140  
 Val Tyr His Thr Gln Gly Tyr Phe Pro Asp Trp Gln Asn Tyr Thr Pro  
 145 150 155 160  
 Gly Pro Gly Ile Arg Phe Pro Leu Thr Phe Gly Trp Cys Phe Lys Leu  
 165 170 175  
 Val Pro Val Glu Pro Glu Lys Val Glu Glu Ala Asn Glu Gly Glu Asn  
 180 185 190  
 Asn Cys Ala Ala His Pro Met Ser Gln His Gly Ile Glu Asp Pro Glu  
 195 200 205  
 Lys Glu Val Leu Glu Trp Arg Phe Asp Ser Lys Leu Ala Phe His His  
 210 215 220  
 Val Ala Arg Glu Leu His Pro Glu Tyr Tyr Lys Asp Cys  
 225 230 235

&lt;210&gt; SEQ ID NO:9

&lt;211&gt; LENGTH: 4945

&lt;212&gt; TYPE: DNA

&lt;213&gt; ORGANISM: E. coli

&lt;400&gt; SEQ ID NO:9

tcgcgcggtt	cggatgatgac	ggtgaaaacc	tctgacacat	gcagctcccg	gagacgggtca	60
cagcttgtct	gtaagcggat	gccgggagca	gacaagcccg	tcagggcgcg	tcagcgggtg	120
ttggcgggtg	tcggggctgg	cttaactatg	cgccatcaga	gcagattgta	ctgagagtg	180
accatatg	gtgtgaaata	ccgcacagat	gcgtaaggag	aaaataccgc	atcagattgg	240
ctattggcca	ttgcatacgt	tgtatccata	tcataaatatg	tacatttata	ttggctcatg	300
tccaacatta	ccgccatggt	gacattgatt	attgactagt	tattaatagt	aatcaattac	360
ggggtcatta	gttcatagcc	catatatgga	gttccgcgtt	acataactta	cggtaaattg	420
cccgctggc	tgaccgcca	acgaccccg	cccattgacg	tcaataatga	cgtatgttcc	480
catagtaacg	ccaataggga	ctttccattg	acgtcaatgg	gtggagtatt	tacggtaaac	540
tgcccacttg	gcagtacatc	aagtgtatca	tatgccaaat	acgcccccta	ttgacgtcaa	600
tgacggtaaa	tggcccgcc	ggcattatgc	ccagtacatg	accttatggg	actttcttac	660
ttggcagtac	atctacgtat	tagtcacgc	tattaccatg	gtgatgcgg	tttggcagta	720
catcaatggg	cgtggatagc	ggtttgactc	acggggattt	ccaagtctcc	acccattga	780
cgtcaatggg	agtttgtttt	ggcaccaaaa	tcaacgggac	tttccaaaat	gtcgtaaaca	840
ctccgcccc	ttgacgcaaa	tgggcggtag	gcgtgtacgg	tgggaggctc	atataagcag	900
agctcgttta	gtgaaccgtc	agatcgccgt	gagacgccat	ccacgctggt	ttgacctcca	960
tagaagacac	cgggaccgat	ccagcctccg	cggccgggaa	cgggtgcattg	gaacgcggat	1020
tcccgtgccc	aagagtgcg	taagtaccgc	ctatagactc	tataggcaca	cccctttggc	1080
tcttatgcat	gctatactgt	ttttggcttg	gggcctatac	acccccgctt	ccttatgcta	1140
taggtgatgg	tatagcttag	cctatagggt	tgggttattg	accattattg	accactcccc	1200
tattggtgac	gatactttcc	attactaatc	cataacatgg	ctctttgcc	caactatctc	1260
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&lt;211&gt; LENGTH: 4867

&lt;212&gt; TYPE: DNA

&lt;213&gt; ORGANISM: E. coli

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<210> SEQ ID NO:17
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<212> TYPE: DNA
<213> ORGANISM:Artificial Sequence

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<220> FEATURE:
<223> OTHER INFORMATION: oligonucleotide

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<210> SEQ ID NO:18
<211> LENGTH: 78

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<212> TYPE: DNA  
<213> ORGANISM:Artificial Sequence

<220> FEATURE:  
<223> OTHER INFORMATION: oligonucleotide

<400> SEQ ID NO:18  
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cttcattgca tccatgg 78

<210> SEQ ID NO:19  
<211> LENGTH: 27  
<212> TYPE: PRT  
<213> ORGANISM:Homo sapien

<400> SEQ ID NO:19  
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<213> ORGANISM:Artificial Sequence

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<220> FEATURE:  
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<210> SEQ ID NO:24  
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<210> SEQ ID NO:25  
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<220> FEATURE:  
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<213> ORGANISM:E. coli

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&lt;213&gt; ORGANISM: E. coli / HIV-1

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<212> TYPE: DNA  
<213> ORGANISM: E. coli / HIV-1

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<210> SEQ ID NO:29  
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<212> TYPE: DNA  
<213> ORGANISM: E. coli / HIV-1

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<210> SEQ ID NO:30  
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<213> ORGANISM: Human Immunodeficiency Virus - 1

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accaatgctg attgtgcttg gctagaagca caagaggatg aggaagtggg ttttcagtc 240  
agacctcagg tacctttaag accaatgact tacaaggag ctgtagatct tagccacttt 300  
ttaaagaaa aggggggact ggaagggcta attcactcac agaaaagaca agatattcctt 360  
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tttcatcacg tggcccagaga gctgcatccg gagtactaca aggactgctg a 651

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization  
International Bureau



(43) International Publication Date  
21 June 2001 (21.06.2001)

PCT

(10) International Publication Number  
**WO 01/43693 A3**

- (51) International Patent Classification<sup>7</sup>: C07H 21/04. C12N 15/00. A61K 39/00 (74) Common Representative: MERCK & CO., INC.: 126 East Lincoln Avenue, Rahway, NJ 07065-0907 (US).
- (21) International Application Number: PCT/US00/34162 (81) Designated States (*national*): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CR, CU, CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.
- (22) International Filing Date:  
15 December 2000 (15.12.2000)
- (25) Filing Language: English
- (26) Publication Language: English
- (30) Priority Data:  
60/172,442 17 December 1999 (17.12.1999) US (84) Designated States (*regional*): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).
- (71) Applicant (*for all designated States except US*): MERCK & CO., INC. [US/US]; 126 East Lincoln Avenue, Rahway, NJ 07065-0907 (US).
- Published:  
— with international search report
- (72) Inventors; and (88) Date of publication of the international search report:  
21 February 2002
- (75) Inventors/Applicants (*for US only*): SHIVER, John, W. [US/US]; 126 East Lincoln Avenue, Rahway, NJ 07065-0907 (US). LIANG, Xiaoping [CA/US]; 126 East Lincoln Avenue, Rahway, NJ 07065-0907 (US). FU, Tong-Ming [US/US]; 126 East Lincoln Avenue, Rahway, NJ 07065-0907 (US).
- For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.*

WO 01/43693 A3

(54) Title: POLYNUCLEOTIDE VACCINES EXPRESSING CODON OPTIMIZED HIV-1 NEF AND MODIFIED HIV-1 NEF

(57) Abstract: Pharmaceutical compositions which comprise HIV Nef DNA vaccines are disclosed, along with the production and use of these DNA vaccines. The nef-based DNA vaccines of the invention are administered directly introduced into living vertebrate tissue, preferably humans, and express the HIV Nef protein or biologically relevant portions thereof, inducing a cellular immune response which specifically recognizes human immunodeficiency virus-1 (HIV-1). The DNA molecules which comprise the open reading frame of these DNA vaccines are synthetic DNA molecules encoding codon optimized HIV-1 Nef and derivatives of optimized HIV-1 Nef, including nef modifications comprising amino terminal leader peptides, removal of the amino terminal myristylation site, and/or modification of the Nef dileucine motif. These modifications may effect wild type characteristics of Nef, such as myristylation and down regulation of host CD4.

# INTERNATIONAL SEARCH REPORT

International application No.

PCT/US00/34162

<b>A. CLASSIFICATION OF SUBJECT MATTER</b> IPC(7) : C07H 21/04; C12N 15/00; A61K 39/00 US CL : 536/23.4; 435/320.1; 424/184.1 According to International Patent Classification (IPC) or to both national classification and IPC		
<b>B. FIELDS SEARCHED</b> Minimum documentation searched (classification system followed by classification symbols) U.S. :  Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched  Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) Medline, caplus, biosis, embase, scisearch, wpids.		
<b>C. DOCUMENTS CONSIDERED TO BE RELEVANT</b>		
Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	TOBERY, T. et al. Cutting Edge: Induction of Enhanced CTL-Dependent Protective Immunity in vivo by N-End Rule Targeting of a Model tumor Antigen. 15 Jan 1999, 162 (2) 639-642. (see abstract)	1,2,6,7,20-22, 26-28.
X	GIRARD, M. New prospect for the development of a vaccine against human immunodeficiency virus type 1. An overview. Comptes Rendus de L Academie Des sciences. Serie III, Sciences de la vie, November 1999, 322 (11) 959-66.	1,2,6,7,20-22, 26-28
Y	US 5,851,813 A (DESROSIERS) 22 December 1998, see abstract	1,2,6,7,20-22, 26-28
<input type="checkbox"/> Further documents are listed in the continuation of Box C. <input type="checkbox"/> See patent family annex.		
Special categories of cited documents:		
"A" document defining the general state of the art which is not considered to be of particular relevance	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principles or theory underlying the invention	
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"O" document referring to an oral disclosure, use, exhibition or other means	"&" document member of the same patent family	
"P" document published prior to the international filing date but later than the priority date claimed		
Date of the actual completion of the international search May 4, 2001	Date of mailing of the international search report 06 JUN 2001	
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703)305-3230	Authorized officer Eleanor Sorbello <i>Eleanor Sorbello</i> Telephone No. 703-308-0196	

# INTERNATIONAL SEARCH REPORT

International application No.

PC 300/34162

## Box I Observations where certain claims were found unsearchable (Continuation of Item 1 of first sheet)

This international report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claim Nos.:  
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☒ Claim Nos.: 3-5,8-19,23-25 and 29  
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:  
Please See Continuation Sheet
3. ☐ Claim Nos.:  
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

## Box II Observations where unity of invention is lacking (Continuation of Item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐  
☐

The additional search fees were accompanied by the applicant's protest.

No protest accompanied the payment of additional search fees.

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/US00/34162

Continuation of Box I Reason2: Claims 3-5, 8-19, 23-25 and 29 were not searched as the application did not comply with sequence rules. The CRF was found to be defective. A CRF Error Report was faxed to Mark Hand on March 3, 2001. However, corrected diskette has not been submitted.



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